NASA TECHNICAL TRANSLATION NASA TT F-15,678

THE CONQUEST OF OUTER SPACE IN THE USSR

Dr. G. S. Narimanov, Ed.

Translation of "Osvoyeniye Kosmicheskogo Prostranstva v SSSR," Nauka Press, Moscow, 1974, 224 pp.

(NASA-TT-F-15678) THE CONQUEST OF OUTER SPACE IN THE USSR (Karmen (Leo) Associates) 454 p HC $26.25 CSCL 22C

N74-30280

Unclas
G3/30 54516

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 July 1974

STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TT F-15,678		

4. Title and Subtitle	5. Report Date
THE CONQUEST OF OUTER SPACE IN THE USSR	July 1974
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Dr. G. S. Narimanov, Editor-in-Chief	
	10 Work Unit No

9. Performing Organization Name and Address	11. Contract or Grant No.
Leo Kanner Associates Redwood City, California 94063	NASw-2481
	13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Osvoyeniye Kosmicheskogo Prostranstva v SSSR," Nauka Press, Moscow, 1974, 224 pp.

16 Abstract The collection contains TASS reports and articles by leading scientists printed during 1972, showing the achievements of the Soviet Union in the conquest of outer space. The collection reflects the major phases of space research. See table of contents for subject matter of the various articles.

17. Key Words (Selected by Author(s))	18. Distribution Statement
	Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	464	

NASA-HQ

ANNOTATION

Editor-in-Chief G. S. Narimanov,
Dr. of Physical and Mathematical Sciences

The collection contains TASS reports and articles by leading scientists printed in the Central Press during 1972, showing the achievements of the Soviet Union in the conquest of outer space. The main phases of space research are reflected in the collection: successful flights of Luna-20 and Venera-8 space stations, launches of Kosmos, Meteor, Molniya spacecraft and two new Prognoz scientific stations. There is material on international cooperation artificial earth satellite launchings in the Interkosmos series and the French small independent satellite (SIS), and also work on the preparation of the joint flight of the Soyuz and Apollo manned spacecraft.

PREFACE

G. S. Narimanov, Dr. of Physical and Mathematical Sciences

"Artificial earth satellites pave the way for interplanetary journeys" -- this was the way in which TASS reported the launching of the first artificial earth satellite on October 4, 1957. Each new launch and each new step to the stars convince us of the truth of these words.

Only two satellites were launched into near-earth orbit in 1957. In 1972, our country celebrated the 15th anniversary of the day on which the first artificial earth satellite was launched. By 1973, the number of satellites in the Kosmos series alone was 542, apart from this there are also Polet, Zond, Electron, Molniya, Meteor and Prognoz...

There is no need to give a chronicle here of all the events occurring over the past years. Let us simply state that much of which man could not even have dreamed has already taken place.

In an amazingly short space of time satellites, spacecraft and automatic interplanetary stations have provided unique scientific material and led to many outstanding discoveries.

The amount of scientific and technical problems to be solved by space technology increases yearly. Astronautics has entered into man's everyday life, facilitates long-distance communications, and contributes to air navigation and navigation at sea. Satellite

meteorology has now become an independent branch of the science of weather. Weather forecasting can be made more reliable by using television and infrared images of the earth for daily analysis of the planetary distribution of cloud cover.

Obviously, the next few years will be a period for the intensive construction of "economic" and manned orbital research stations. The sphere of interest of astronautics will not only be near-earth space. Of course, the moon will not be forgotten. It will be extremely important to set up on the moon a permanently active scientific base, although much research with automatic scientific instruments placed on the moon's surface must be carried out before this takes place.

1972 was marked by a great achievement of Soviet astronautics -- new samples of earth soil from the mountain region of our "neighbor" were brought back to earth by Luna-20.

As before, astronautics is interested in planets of the solar system. On July 22, the automatic interplanetary station Venera-8 reached Venus and a descent vehicle made a soft landing on its surface and transmitted much valuable scientific information. Mars-2 and Mars-3 automatic interplanetary stations have carried out scientific research programs.

Naturally, the further conquest of outer space entails the solution of a number of difficult technical, medical and biological problems. The further advance of man into space will depend mainly on how they are solved. This year two Prognoz scientific stations

have been launched to study solar activity and its effect on the interplanetary medium and the earth's magnetosphere.

Artificial earth satellites Interkosmos-6, Interkosmos-7 and Interkosmos-8 were launched in the Interkosmos program with socialist countries. During the past year, cooperation with France was expressed in the launch of a French small independent satellite in the Soviet Union.

In 1972 a treaty was concluded between the USSR and the USA on cooperation in research and the use of outer space for friendly purposes. In the light of this document, a number of meetings took place for preparing a joint flight of manned Soyuz and Apollo spacecraft in 1975.

As opposed to the three previously published collections, this publication includes articles published in 1972 in the Central Press and also several articles from popular science journals[1]. A considerable amount of the material throws light on questions of the further conquest of space, and problems and prospects of space research facing scientists. The wide range of questions, diversity of subject and systematic choice of material make the collection useful not only for specialists and scientists, but for all those interested in space research.

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1 The headings of newspaper material are somewhat changed in accordance with the requirements of book publications. Part of the text of articles and some drawings have been omitted due to the limited volume of the book: a number of photographs are taken from the TASS pictorial review.

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INTRODUCTION

Conquest of Space: A New Phase

TASS

"Pravda", April 13, 1972

A Grand Rally Dedicated to Astronautics Day

On April 12, a grand rally was held in the Kremlin dedicated /5* to Astronautics Day. Among those at the rally to mark the 11th anniversary of Yuri Gagarin's flight were workers, scientists, designers, engineers dealing with astronautic problems, producers of space equipment, representatives of party, Soviet and Moscow's public organizations, and troops of the Moscow garrison. Heads of diplomatic representatives accredited in the USSR, and Soviet and foreign journalists were present.

A storm of applause greeted the arrival of Comrades L. I. Brezhnev, G. I. Voronov, V. V. Grishin, A. P. Kirilenko, A. N. Kosygin, F. D. Kulakov, K. T. Mazurov, D. S. Polyanskiy, M. A. Suslov, A. N. Shelepin, Yu. V. Andrapov, P. N. Demichev, M. S. Solomentsev, D. F. Ustinov, K. F. Katushev. In the presidium were deputies of the Chairman of the Council of Ministers of the USSR, Ministers of the USSR and space pilots.

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* Numbers in the margin indicate pagination in the foreign text.

The whole hall applauded young Pioneers who presented bouquets of flowers to party and government leaders, scientists, space pilots and to all those in the presidium.

A grand rally of representatives of Moscow city workers and troops of the garrison, dedicated to Astronautics Day was opened by V. F. Promyslov, the Chairman of the Executive Committee of the Moscow Municipal Council of Deputies of Workers.

The hall resounded to the Hymn of the Soviet Union.

M. V. Keldysh, the President of the Academy of Sciences of the USSR, was introduced.

M. V. Keldysh's Speech

This year we celebrate Astronautics Day on the eve of a famous date, the 50th anniversary of the formation of the USSR. Fifty years have passed since Lenin conceived the idea of creating the first multi-national state of workers and peasants in the world. During this period, the Soviet Union has made progress unprecedented in man's history: an agricultural, industrially-backward country has been transformed into a powerful industrial power capable of changing man's most daring dreams into reality. This is clearly borne out by the great achievements of Soviet astronautics.

In a speech given by the Secretary General of the Central /6
Committee of the Communist Party of the Soviet Union, Leonid Il'ich Brezhnev, at a pre-election meeting of voters at the Bauman electoral district in Moscow, it was stated that Soviet science has

achieved new outstanding successes, especially in research into space and heavenly bodies. The research conducted is in the interest of the Soviet people and mankind as a whole.

It has become a tradition on April 12 of each year on Astronautics Day, to review our country's achievements in space. Last year was marked by the great successes in all types of space research. The use of astronautic achievements is being widened for national economic requirements. With this in mind, space radio and television communications systems are being improved and this leads to systematic research from space into meteorology and other spheres of knowledge linked with the study and rational use of the natural environment.

The greatest achievement last year was the building of the Salyut orbital scientific station which stayed in orbit for approximately six months. The heroic crew, consisting of space pilots Georgiy Timofeyevich Dobrovol'skiy, Vladislav Nikolayevich Volkov and Viktor Ivanovich Patsayev, worked for 24 days. The Soviet people and the world as a whole was grieved to hear of the unexpected death of the astronauts, after successfully carrying out the flight program, when returning to earth in the Soyuz-11 transport spacecraft, when one of the components in the pressure regulated system failed. Three heroic Soviet astronauts dedicated their lives to space research in the name of science, the future and the good of mankind. The work they did made for a great step forward in the development of astronautics.

The Salyut station was sent into orbit on April 19, 1971. It was the natural result of successive and systematic implementation of our country's space program. Important space experiments have been conducted for several years -- they are stages required for creating such stations. The Soyuz-10, with its crew consisting of V. A. Shatalov, A. S. Yeliseyev and N. N. Rukavishnikov, carried out the first rendezvous and docking with the Salyut station.

The Salyut orbital scientific station is, in principle, a new type capable of solving a wide range of important questions of science, technology and the national economy. The overall volume of the station is approximately 100 cubic meters; it is about 20 meters in length; and the weight of the orbital complex is more than 25 tons. This allowed comfortable conditions for the crew not only for prolonged work but for rest and for physical exercises. The station's main compartment is a space laboratory. This compartment contains equipment for controlling the station, a life support system, reserves of food and water and scientific instruments. The first manned orbital station is an outstanding achievement for our country and marks the beginning of a new stage in the conquest of outer space.

Flights of Soviet spacecraft to the moon and planets showed that automatic control units have unlimited possibilities. They can carry out a wide range of scientific research, from obtaining the first "sounding" information, to the systematic and profound study of heavenly bodies and of physical processes in space.

In accordance with directives sanctioned by the 24th Congress of the Communist Party of the Soviet Union, we see the general line of Soviet astronautics as the rational combination of automatic and manned methods for discovering the universe for the good of all mankind.

Over the past year, important new results have been obtained /7 in the study of the moon. I will remind you of the prolonged work on the moon's surface by the Lunokhod-1 which allowed us to determine the general type of rock making up the surface of a typical lunar "sea", and investigate the nature of the extent of small craters and stones. In September of last year, a new artificial moon satellite was launched -- the Luna-19 station. On February 25, 1972 a new complex experiment was completed -- a re-entry vehicle of the Luna-20 automatic station brought back to earth rock samples from the mountainous region of the moon's surface. This solved the difficult scientific and technical problem of landing an automatic control unit on the moon's almost inaccessible continental region.

The sample of lunar soil brought back to earth is now undergoing detailed research. It can already be said that it varies significantly from lunar samples studied earlier, both in outward appearance and in minerological composition.

The delivery of soil from the continental region is an important step in the successive program of research into the moon's substance and opens up great possibilities for studying old sections of the lunar surface where unique rocks rich in aluminum

appear on the surface. This gives us a better idea of the earth's ancient history, where primary rocks were changed during later evolution or disappeared.

I shall describe our success in studying planets of the solar system closest to the earth. In May 1971, Mars-2 and Mars-3 Soviet automatic stations were launched towards Mars. Putting an automatic station into a specific Mars orbit and landing it on its surface where the atmosphere is extremely rarified are very complex problems, the solution of which depends on perfecting the on-board complex, and the efficient working of ground command and measurement equipment. These problems were solved successfully, and both Mars-2 and Mars-3 became artificial Mars satellites. The first soft landing in history was made on the surface of this planet. Mars-2 and Mars-3 satellites orbited Mars for five months transmitting a great volume of information on the physical features of the planet and outer space surrounding it.

Our country achieved outstanding results in investigating Venus. Recently, the Venera-8 automatic station was launched toward Venus. It will continue research which will allow us to have a better understanding of this planet's complex nature.

Last year new important steps were made to develop the international cooperation of the Soviet Union in studying and conquering outer space for peaceful means.

Interkosmos-5 and -6 satellites, geophysical and meteorological rockets of the cooperation program of socialist countries, the

Oreol satellite and a small automatic satellite, equipment on board the Mars-3 Soviet interplanetary station in the cooperation program with France, -- these are only some examples of successfully developing joint work in space.

The Soviet Union allows foreign scientists to take part in investigating samples of lunar soil brought back to earth by Soviet automatic stations. Analysis of these samples is being done by laboratories in Hungary, Czechoslovakia, France and the USA, apart from Soviet laboratories.

An agreement for creating an international system and organization of space communications "Intersputnik", signed in Moscow in November 1971, will be of great practical importance for space use.

An agreement reached between the Academy of Sciences of the /8
USSR and the National Aeronautics and Space Administration of the USA in January 1971 will develop contacts between Soviet and American scientists in studying outer space, the moon and planets, the natural medium, space meteorology and also space biology and medicine. Ways are being found for reaching an agreement in carrying out work in creating joint methods for the rendezvous docking of Soviet and American manned spacecraft and stations. An important step has been made in expanding cooperation in space research between the Soviet Union and India.

The launch of the first Soviet artificial earth satellite opened the epoch of space research and, in a short space of time,

achieved great successes in science and practical activity. Soviet space researchers are very grateful to our Communist Party and the Political Bureau of the Central Committee of the Communist Party of the Soviet Union for its constant attention. They will work even harder to achieve their aim for the benefit of our people and in the interest of the whole of mankind.

A Speech by A. A. Leonov

From an historical point of view, the time for carrying out practical astronautics is short; nevertheless, space research has entered our lives and has become an important branch of human activity. The conquest of space is one of the most characteristic features of the scientific and technical revolution which is taking place.

Only 108 minutes were required for Vostok manned by Yuri Alekseyevich Gagarin on April 12, 1961 to orbit our blue planet. This not only showed a speed unheard of at this time, but was also man's first step into the boundless starry ocean.

Allow me, on behalf of space pilots, to congratulate all those who built the complex spacecraft and gave them flight. On this Astronautics Day may I wish new success in fulfilling the wide program of the conquest of space laid down by the 24th Congress of Communist Party of the Soviet Union.

The great creative force of domestic science, the economic power of this socialist country is reflected in our victory in

the peaceful conquest of space as in a mirror, and confirms the inexhaustible spiritual potential of the Soviet people.

The Soviet outer space research program includes the use of manned and automatic facilities. The most important part in this program is creating manned long-term orbital stations for scientific and national economic use.

The Soviet Salyut station was the first of such stations. Its crew consisting of Georgiy Timofeyevich Dobrovol'skiy, Vladislav Nikolayevich Volkov, and Viktor Ivanovich Patsayev, worked fruitfully for 24 days in space. All their knowledge, experience and will were concentrated so that each hour of the flight brought maximum benefits, and laid down a reliable basis for the future of Soviet astronautics.

Orbital stations open up wide possibilities for mankind. At the same time, we are aware of the difficulties of a prolonged stay in space and that the exploration and conquest of space -- this new unknown world -- is unthinkable without efforts, great knowledge, courage and will. People will never forget the names of those astronaut heroes who gave their life to the great cause of space conquest.

Whatever trials and dangers await us, they cannot retain man's ardor to discover the secret of the universe. Astronautics is /9 entering a new phase of its development, which entails prolonged space flight, and long stays on board spacecraft.

Space pilots are preparing for new space flights which require great theoretical knowledge, high moral and political and

psychological qualities, physical fitness, complex rocket and space technology and flying skill. We can understand this and are doing everything possible to answer the requirements fully.

This year, the Soviet people celebrates a wonderful occasion -- the glorious 50th anniversary of the Soviet Union. We are proud of the fact that Vladimir Il'ich Lenin was its creator and that the first socialist country in the world became the land of astronautics. Our victories owe much to the glorious working class. Our wonderful workers produce accurate instruments, and assemble satellites, interplanetary stations and spacecraft. When setting out on a flight we, space pilots, feel deeply how much soul, human warmth and craftsmanship our workers have put into its production. May I give my heartfelt thanks to the working class!

Space pilots, as indeed the whole nation, link their successes and achievements, their plans for the future with Lenin's great party. We express our sincere gratitude to the Central Committee of the Communist Party of the Soviet Union and the Soviet Government for its high appraisal of our work and we assure them that we are ready to carry out any task of the Communist Party and its Leninist Central Committee.

Those present accept with great enthusiasm the letter of welcome to the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR.

Orbits of Progress

B. N. Petrov

A hero of Socialist Labor, academician and secretary of the Mechanics and Processes Department of the Administration of the Academy of Sciences of the USSR.
In "Trud", April 12, 1972.

The eleven years since the triumphal flight of Yuri Alekseyevich Gagarin were filled by strenuous and productive labor of Soviet space researchers. Requirements of the national economy, science and technical progress determine our space program, which is calculated for many years ahead.

A large range of questions is normally solved during each space flight. But however diverse they are, there are three directions, three groups of problems which researchers must confront. Firstly, the fundamental research of the earth, the universe, and heavenly bodies in the solar system. The second -- is the use of all those resources which help to open up outer space for the national economy. Finally, the third task is the comprehensive improvement of rocket and space technology, without which further progress in this field is impossible.

The development of the country's space program is, by no means, simple. One must correctly determine the proportions, the ratio of scientific, national economic and technical work in space. This proportion can change significantly over the years, and a certain tendency can be noticed here. It is that the amount of research and experiments of national economic value increases each year.

Another important problem when developing the space program is the optimum solution of the question: Which work in space should be done automatically and which should be done by man equipped with /10 automatic equipment and computers.

Guided by the instructions of our party's Central Committee, Soviet scientists have developed a wide program of long-term work in space research and its use for national economic requirements. This is a method for solving the radical fundamental problems of astronautics, and the basic problems of science and technology.

When conducting research into the conquest of space, Soviet scientists devote much attention to the use of various complex automatic controlled units. We shall give a few examples showing the successes achieved by aeronautics, thanks to the use of automatic vehicles and stations.

Outstanding research into the atmosphere of Venus belongs to the field of scientific experiments. This work received the highest award, the Lenin Prize. Instruments of numerous automatic vehicles are studying the moon and Mars, outer space and the Sun, and the earth itself. The delivery of lunar soil to earth by automatic vehicles, a landing on Venus and Mars, and the unparalleled feat of Lunokhod-1 are achievements in space technology which startled the world.

Fruitful work has been done for ten years in the Kosmos program. Even today one can feel the real effect from using these vehicles. For example, in 1963 work was started on producing meteorological satellites. The development of equipment and

satellite-synoptic meteorologists' systems was done in Kosmos Nos. 14, 25, 122, 144, 156, 184. In 1969 the Meteor, a reliable operational variant of the weather satellite, was produced. Since then, Meteors have carried out continuous observation above the planet. New satellites replace those which have outlived their time. Eleven such vehicles have been launched and are transmitting valuable weather information on the whole planet to the Hydrometeorological Center of the USSR.

Soviet Meteor and American Essa weather satellites have detected the origin of such powerful hurricanes as Betsy, Esther, and typhoons Nancy, and Pamela. Inhabitants of coastal areas were warned of their approach in good time, and this significantly reduced the amount of destruction and human casualties caused by them.

Automatic reconnaissance vehicles are also very effective in far space when investigating other planets and probing the limitless space of the universe.

American specialists also make great use of automatic vehicles in near-earth space and when studying neighboring planets. American weather and communications satellites are now in orbit, and the USA has launched spacecraft to Venus and Mars. This year, the first reconnaissance vehicle was launched from Cape Kennedy towards Jupiter.

However, Soviet and American specialists have significantly different approaches to manned space research flights. After

Gagarin's Vostok was launched, and after John Glenn's flight, both countries were faced with the problem: How much further must the manned flights' program be developed, and what problems must man solve in space?

Soviet scientists came to the conclusion that man must also work in near-earth orbits to give the greatest returns to science and the national economy. Therefore, Vostok, Voskhod and the improved Soyuz spacecraft-laboratory were used. A number of independent scientific and applied problems were solved during their flights. Simultaneously, technical questions were studied for /11 producing long-term orbital stations. In our opinion, man can work for the longest time and most fruitfully in space from such stations as these.

The production of long-term orbital stations is the general trend in the Soviet program of manned flights. This technique must become the decisive means for developing near-earth space. This trend and strategy in manned space flights is being carried out in our country consistently and systematically.

A result of this was the launch of the Salyut, the first long-term orbital station. On April 24 of last year, astronauts V. A. Shatalov, A. S. Yeliseyev and N. N. Rukavishnikov in Soyuz-10 carried out a series of experiments in a joint flight with the Salyut station. A number of new docking devices were tested.

On June 7, 1971, astronauts from the Soyuz-11 arrived on Salyut. The first manned long-term orbital satellite began to function. Its heroic crew, G. T. Dobrovol'skiy, V. N. Volkov and

V. I. Patseyev carried out a flight which was unparalleled in duration, and a large number of scientific and technical experiments was conducted.

Soviet specialists are continuing work in this direction. Following the first experimental long-term orbital laboratory in near-earth orbits, new ones are appearing. Their crews will be able to solve a wider range of scientific and national economic problems. American specialists have chosen a completely different direction for manned launches. The aim of their program is a manned flight to the moon. Here, they have been very successful.

Research into the moon, in the Soviet space program, is done with automatic stations. The research conducted by the Lunokhod-1 and the return to earth of lunar soil, including that from the almost inaccessible continental region, once more convinced us that study of the moon by automatic vehicles is extremely effective. It is also important that launching of an automatic vehicle is ten times cheaper than a manned expedition to the moon.

What of space in the future? First of all, it must be a place for the close cooperation of different countries and peoples. Life shows us that the returns from developing the universe can be increased if one unites the scientific and technical potential of several countries.

Therefore, we believe it is important to develop international cooperation when carrying out space projects. Socialist countries carry out joint work in Interkosmos. Six artificial satellites have been launched, as have several rockets for vertical probing of

the atmosphere and adjacent space. A number of important scientific results have been obtained. This work can be significantly developed and broadened in the future.

A business-like cooperation has been set up between Soviet and French space researchers. France's participation in Lunokhod-1 and Mars-3 experiments and in the Oreol satellite, the launching of a small French independent satellite "SIS" by a Soviet rocket and the development of cooperation in space meteorology are only the first joint steps of the two countries in space research and the use of it. This is a good example of the fruitful cooperation of states with different social structures, but uniting in order to solve important scientific and technical problems.

In recent years, the complex use of different equipment already makes it possible for space to be one of the most promising areas of scientific research and the effective solution of national economic problems. This is the main aim of the Soviet space program -- the use of space for the benefit of mankind, in the name of peace and progress. /12

The Future of Orbital Stations

K. P. Feoktistov

Professor, hero of the Soviet Union, space pilot of the USSR. "Sovetskaya Rossiya", April 12, 1972.

The Soviet Salyut station worked for almost six months in near-earth orbit. Detailed analysis of material obtained as a

result of this research is still not complete, but one can say with certainty that this flight played an important part in the conquest of outer space and development of space technology.

One of the main tasks of the Salyut was the comprehensive check of the station's serviceability, equipment, and systems for providing space flight in actual conditions. This task was completely accomplished.

So that these results become more clear, I will remind you of the complex nature of a vehicle such as the Salyut. The station contains approximately 2,000 instruments, units and components (it is true that many of these are identical, but there are more than several hundreds of different instruments). There are approximately 100 electromotors alone in different on-board systems, and 20 control panels, not counting control members and control panels on individual experimental instruments. The overall length of electric wires is hundreds of kilometers.

The whole complex equipment worked continuously. This means that when producing the Salyut it was possible to find relatively simple and reliable solutions for all station systems and units. All this was done, as they say, at the first attempt: indeed, the Salyut is the prototype of the orbital laboratory.

The second problem is no less important. The prospects for the further development and the construction of orbital stations, to a great extent, depend on how long a man can remain in weightlessness. In fact, if it happens that man cannot remain long in

weightlessness, one must look for new solutions for the prolonged functioning of an orbital station. It is possible that this can be done in two ways.

The first is creating artificial gravity in orbital stations. At present, we can only see the solution of this problem by the rotation of the spacecraft. But if the whole station rotates, it is practically impossible to carry out astrophysical research, observe the surface of the earth and carry out work in weightlessness conditions. Consequently, the station's main work compartments must be stationary, and the living module must rotate. One can quickly see the technical difficulties which occur when developing orbital stations with artificial gravity. It is clear that they will cost much more and be heavier than stations without artificial gravity.

The second method is to produce "visited" orbital stations which work automatically. The crew of a "visited" station only disembarks occasionally to check, adjust and inspect the equipment.

Of course, both methods require the construction of more complex and expensive stations in comparison with those where the crew is in weightlessness. This is why it is important to establish how long man can work outside of earth's gravity.

In the Salyut a new step was made to increase the duration of manned flights. As is known, space pilots G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev lived and worked on the station for 23 days. /13

Information obtained during this prolonged flight showed that astronauts contended with weightlessness conditions completely satisfactorily.

The Salyut carried out research in astrophysics, medicine and biology, and technology. A series of experiments was conducted for the national economy. Much of the research carried out gave new results.

At the same time, an incidental result was obtained not envisaged by the program. Until then, astronauts had not been required to deal with such an amount of scientific equipment. Of course, the complication is not in the fact that the overall weight of the Salyut's equipment is reckoned in tons, but in tens of kilograms. It is simply that the amount of instruments with which the crew must deal is too great.

At the same time, experience showed that astronauts had no sense of time when carrying out research. Weightlessness, of course, considerably complicated the work. It is good that we have understood this by no means trivial feature of research activity in space through the experience of the Salyut flight.

Of course, it does not follow that in the future one must ignore the multi-purpose role of orbital stations. The era of thorough research of our planet and the world surrounding us by using manned spacecraft is only beginning. Also insufficient is still known on whether we can go over to using highly-specialized orbital stations. The wider the front of research, the greater

are the chances for a successful solution of facts and regularities. A station manned by qualified researchers makes it possible to increase the amount of research.

I am convinced that a reliable means of increasing the equipment efficiency of an orbital station is the further automation of the most frequently repeated operations and station control processes of its equipment and scientific instruments. Then, the crew will be able to devote more time to the main task -- scientific research and observations.

The Starry Spring

A. Yeliseyev

Space pilot of the USSR.
"Sotsialisticheskaya industriya", April 12, 1972.

It is probable and very symbolic that it was in spring, when nature reawakens, that man first flew into space. Delighted by Yuri Gagarin's feat, and our scientific and technical achievements, at that time we understood this event more with our heart than our mind. Only later did we realize that the spring of 1961 was the turning point in the history of the earth: here, the era of man's flights into outer space had begun.

One year ago we celebrated the 10th anniversary of that era. In the tradition of celebrations we remembered past launches of Vostok, Voskhod and Soyuz, flights of automatic probes to the moon and distant planets, and numerous experiments "in the region" of

the earth and Sun. Taking account of the past, we unwittingly are amazed by how much has been done during the past ten years, but mainly by the speed at which astronautics has progressed.

In fact, only a year has passed and how many events have /14
taken place in space! Scarcely had the country celebrated Astronautics Day when a new powerful launch vehicle put the first long-term manned scientific spaceship Salyut into orbit. My friends and I became acquainted with this unique orbital laboratory during the preparation period for the flight on the Soyuz-10. We understood its equipment well; nevertheless, the sight of the station in space made a deep impression upon us. Even the outward appearance of Salyut amazed us by its size, the amount of antennas, and the abundance of instruments and equipment of every kind. Georgiy Dobrovol'skiy, Vladislav Volkov and Viktor Patsayev spent more than three weeks in space on board this station carrying out a program of scientific research and experiments of unprecedented complexity and variety.

Automatic vehicles are continuing the research into the universe at full speed. Surpassing our wildest expectations, Lunokhod-1 carried out investigation of the moon's surface for more than ten months. The Luna-19 automatic station collected much interesting information on our planet's natural satellite when in near-moon orbit. Finally, Luna-20 which recently returned, brought back to earth samples of soil from the almost inaccessible mountainous region of the moon. Last year "long-range" astronautics had great success: two Soviet automatic stations reached Mars and

became natural satellites of it. Here, a capsule which was detached from the Mars-2 station, placed a pennant with the emblem of the Soviet Union on the planet, and a descent vehicle from Mars-3 made a soft landing for the first time on the surface of Mars.

Even in launches during the past year, one can see that the development of space technology today goes in two main directions. One of them is the use of manned spacecraft and orbital stations, the increase of research capabilities and use of unmanned automatic vehicles. Both these and other methods have their doubtless advantages. The problem is to decide upon the correct balance in the two directions and use their advantages to maximum effect.

It is obvious that manned spacecraft have greater potentiality than unmanned ones. But, in order to carry out wide research in orbital stations or manned flights to the planets of the solar system, one must create means which allow man to remain in space for a prolonged time and fly great distances. Many complex problems must be solved to achieve this aim. Ways of solving these problems were frequently unknown previously.

In actual fact, by sending vehicles to distant planets we wish to study the conditions on their surface and in surrounding space. But in order that these vehicles perform this task, they must not only be equipped by the appropriate instruments, but be given specific "survivability". For this, one must have information of those very conditions which are to be studied by the launch.

Therefore, one must solve problems, as it were, by successive approximations.

It has been my pleasure to have been in space three times. In retrospect, I can say that programs of these flights, in essence, are a chain of final "approximations" for solving the problem, such as the creation of the Soyuz-Salyut. The first "approximations" were made in the Kosmos series of satellites, which were automatically docked in orbit. Just as today, the components of future manned spacecraft, control and temperature /15
control system, communications and much more are developed in many automatic vehicles. When automatic stations go into orbit, we know that they are bringing us nearer to the fulfillment of our cherished aim -- manned flights to distant planets.

The achievements of Soviet astronautics are well-known. Behind them is the party work, the government, the joint effort of the whole nation, and various branches of the national economy. When one thinks of the strategy behind our triumphs, one must unwittingly come to the conclusion that the success is the close cooperation of science and practice with which our whole space program was carried out. Designers of space systems are always trying to use the latest results of scientific research in their projects. In their turn, problems which frequently confront us are given concrete expression in scientific investigation, and by the same token, make the solution of practical problems possible. Most of all, developers in space technology have directly

participated in all types of tests, launch preparation and have even been into space in order to test in practice the principles of proposals they made. Many technical solutions were suggested by engineers, technicians and workers of space institutes, testers, cosmodrome workers and, of course, space pilots. This fruitful exchange of opinion and close cooperation have considerably reduced the time for solving the most complex problems.

Behind us are eleven years of manned flight, and hundreds of unmanned vehicle launches. From those impetuous 108 minutes of the first Vostok flight, astronautics have proceeded to create long-term orbital stations, automatic vehicles have landed on the moon, Venus and Mars, Molniya satellites have become an indispensable means of communication, and Meteor satellites carry out space reconnaissance of the weather.

Space has become an arena for international cooperation. Six Interkosmos satellites have been launched and taken into orbit scientific equipment produced by the joint efforts of specialists of socialist countries. A whole series of joint experiments was conducted with French researchers.

Unfortunately, the past few years have not only seen successes. There have been the premature deaths of such outstanding scientists as academicians S. P. Korolev and M. K. Yangel', designers G. N. Babakin and A. M. Isayev. Yuri Gagarin, Vladimir Komarov, Georgiy Dobrovol'skiy, Vladislav Volkov, Viktor Patsayev died when carrying out space duties, as did Pavel Belayev. But they left

behind them not only the grief of loss. They bequeathed to us their dreams, plans and duties. There will be new launches and flights. Man will become an equal master not only on earth but in space. With each new step forward people will remember with gratitude the names of pioneers who opened up the spring of the space age to mankind. Their heroism, talent and devotion to the cause inspires us to new conquests in the name of our people, country and great Leninist party.

Space and Geology

A. Sidorenko

Academician, Minister of Geology of the USSR.
"Nauka i zhizn'", No. 5, 1972.

Probably, we have not fully realized that mankind has entered a new space age of his own development. All research work into neighboring planets and interplanetary space, now even more both directly and indirectly, will affect the development of various sciences and man's economic activity. That is why the 24th Congress of the Communist Party of the Soviet Union, in its directives promised, during the new five-year period, to "carry out scientific /16 work in space to develop long-range telephone and telegraph communication, television, meteorological forecasting and study of natural resources, geographic research and the solution of other national economic problems by using satellites, automatic and manned vehicles and to continue fundamental scientific research

into the moon and planets of the solar system". In this way, space research is being put to direct practical use.

For a long time, geology has traced the development of astronomy, and has used cosmogonic hypotheses. This was needed to understand the overall problems of the earth's development. K. E. Tsiolkovskiy, the founder of astronautics, when developing the theoretical fundamentals of space research, became greatly interested in geological sciences and even published a number of articles and pamphlets on geology. This not only shows the wide learning of their author, but also the unity between geology and astronautics, without which it is impossible to discover the universe.

In this article we shall not deal with the value of geology for developing astronautics. It is quite understandable that without the corresponding level of development of science and technology (in both cases geology plays an important role), it would be impossible for man to go into space and carry out there systematic, ever-increasing research. Let us simply remember that geological methods are being used more widely when researching into other bodies of the universe: geophysical and aerogeological observations from space; the drilling of lunar soil and the geological study of lunar rock; geomorphological, geophysical and geochemical research into the lunar surface by using automatic vehicles, including the most perfected of these, the Lunokhod-1; and directly by man, compiling "geological" maps of the moon, etc.

The role of geological sciences in discovering the universe will increase with the development of space research. Without geological knowledge it is impossible to interpret information on the universe which will be obtained by space research. At the same time, study of outer space and the planets will help us to understand better geological processes taking place deep inside the earth.

Therefore, it is advisable to discuss the possible links between astronautics work and the whole range of research into the earth's crust by geological science methods.

From the moment when the first artificial earth satellite was launched in 1957, it became clear that space flight would open up new possibilities for studying the earth as a planet as a whole, the earth's crust -- the primary source of all original substances for man's existence, and the biosphere -- man's habitable medium. In fact, even now we have information obtained from artificial earth satellites which is used widely for solving many scientific and practical problems in meteorology, geography, oceanography, topography, glaciology, that is, in sciences closely linked with geology. Information obtained by space research methods are acquiring more importance for geology itself.

Geologists have been trained to use new information on our planet obtained by space research by many years experience of aerogeological work. The great value of aerial photographs in geological research is well known.

Aerogeological methods have quickly been recognized since they opened up new ways of developing geology. Aerial photographs gave the geologist a wide field for research, that is, the ability to see simultaneously a relatively large area and trace the shape, dimensions and directions in which individual geological bodies /17 (groups of rock strata, blocks of magnetic rock, etc.) run and structural forms (folded structures, defects in the earth's crust), and also their relation to each other. This also showed the limiting nature of aerial methods.

An aerial photograph can cover an area of not more than 400-700 km. The biggest structural geological features go beyond these limits.

Astronautics, in principal, opens new possibilities for studying the planet.

Photographs taken from space show the greatest geographical and geological features of the earth. The scale of these photographs is practically unlimited, and an area of 30-50,000 square kilometers and above can be covered simultaneously by one photograph by using a single technique.

Apart from this large cover, photographs from space have new information which cannot be obtained on the ground or by ground research. We are talking of the integration effect of individual detail in the area's composition, and the separate sections of large structural elements, thanks to which the latter appear in the complete picture. It appears that the higher the observation point, the better it is to observe the earth's depth structure.

The structure of the deepest horizons of the earth's crust trans-illuminates, as it were, the cover of the porous sediments. This integration effect is still an empirical fact. The scientific bases of this phenomenon have still not been explained.

In this way, research from spacecraft not only increases the potential of aerogeology, but also opens up new directions for studying the earth's crust. At the present time, this department of knowledge is beginning to take shape in a new scientific direction -- space geology. There is a large number of problems confronting it aimed at solving many cardinal questions in geological science.

First experiments -- television pictures from meteorological artificial earth satellites and individual photographs taken by space pilots from Soyuz-3, Soyuz-6, Soyuz-7 and Soyuz-8, have provided geologists with much interesting information and have shown the great possibilities for studying the geological structure of the earth's crust.

Television photographs and photographs obtained from spacecraft make it possible to recognize and explain structural elements which were not determined earlier, even during very accurate and qualified geological research. The first material for studying the earth obtained from space shows that many stable scientific concepts now need to be reviewed. Firstly, this concerns the composition, age and position of large folded systems of old platforms and shields, regional (relating to some individual area) and deep faults, ocean deeps and volcanic areas.

As, for example, by using cosmogeological and aerogeological material, some researchers state emphatically that the mobile zone of crumpling and faults in the Ural's folded system continues much further south. Apparently, this mobile zone intersects the deserts of Central Asia, mountainous areas to the south, and continues to towards the Persian Gulf.

Numerous ground observations in the area of the Ustyurt Plateau could not discern fractures in the earth's crust, because this region is covered by a dense layer of sediments: limestones, clays and marls. On television photographs and photographs, taken from an artificial earth satellite, one can clearly see under this cover a series of old geofractures in the earth's crust, formed before these deposits had been laid down. One can show many similar examples when photographs taken from space help us to understand the geology of different regions of the earth. /18

Space geology has only just started to develop. However, one can already indicate much research in geology which can be conducted based on photographs taken from space.

First of all, this is the further development of geological map making, especially in the coverage plan. Much work has to be done here -- compiling new and correcting geological maps of individual areas and of geological maps of continents and oceans as a whole. There are great potentials for those who compile special geological maps: tectonic, metallogenetic, volcanism maps and especially disjunctive (fracture) tectonic maps. Research by space methods into the interaction of old platforms and folded systems,

continents and oceans, the relief features of a bed and also study of the nature of present-day and old tectonic movement should be given special attention. This information is required for understanding the mechanism and formation processes of the earth's crust on a global scale and for elucidating uniformities in the formation of individual geological structures, mainly of continental and oceanic origin. Cosmogeologial methods will allow one to investigate areas which are almost inaccessible when studying by other methods, -- high lands, areas permanently covered by ice and the sea bed.

Information obtained from space, combined with that obtained by ground geological methods, will give new interesting material for studying the distribution of ore areas, regions where there is oil and gas and carbon-bearing basins of the earth, and show new areas which could be promising when searching for mineral deposits.

Space geology will undoubtedly play a leading part in developing laws for the formation and distribution of mineral deposits. This is only one of the important scientific and practical problems of modern geology.

Even today, space research can help considerably to solve purely practical geological problems. For example, giving information on the size of deposits of water beneath the ground in deserts, the long-term study of which, even with aviation, entails great difficulties and great expenditures of time and resources, and to give engineering and geological evaluation of an area with respect to its economic use, or studying seizmoactive areas, etc.

Space research will also play a large role in developing sciences of the earth as a whole, and will integrate our individual concepts of natural processes taking place on earth. Probably, no other type of research would make it possible to embrace the interdependence between geological and physical and geographical processes on earth and between exogenous and endogenous processes (on the earth's surface and in its depths).

Study of the relief and loose cover from space provides valuable material for understanding erosion, and the formation of a whole variety of continental deposits. For example, we can examine the distribution of aeolian, alluvial, and glacial deposits and their connection with the relief and, consequently, with tectonics, climate, etc.

Space and aerogeological research opens up new possibilities for understanding the correlation between the two basic geological structures -- continents and oceans. This will also help to explain the laws of marine sedimentation and how erosion products are transferred from the land to the sea, show the laws governing the formation of seashores, shelf development and advances and regressions of the sea. All these phenomena can only be conceived /19 by covering the earth -- oceans and dry land.

I would like to warn you immediately about oversimplifying the solution of this problem. Study of the earth from space by no means replaces classical methods of geological observations, but only extends their use and gives them a new scientific level. It would be a mistake to curtail ground research by assuming it to be

replaced by space observations. Operational experience in aerogeology shows that it can be successfully developed and only give the best results when combined with ground geological observations. Consequently, space research into geology must be combined and closely coordinated with aerogeological and ground work.

The most interesting objectives shown by space photographs must be checked by ground interpretation, very fine geological surface roots, and detailed mapping, ground geophysical research and, in a number of cases, boring to a depth. Only detailed research can give reliable, scientifically-based treatment of information obtained from space.

One often hears new mineral deposits will be discovered by space research. Unfortunately, reports have appeared in the press saying that photography from space will "reveal minerals", for "oil and gas coincide with bulges of the earth, and water -- with concave structures of the earth's crust", which from space will "determine the content of useful elements in mineral deposits", etc. Such concepts are simply geologically unfounded.

Research from space helps to discover geological structures, where there may be minerals, and helps to understand the laws of the geological formation of the earth's crust and the distribution of minerals in them. Indeed, they are of undoubted value and of invaluable help to geologists searching for minerals.

There is still one aspect showing the importance of linking space research with geological problems.

For a long time geologists have been interested in the astral, that is, the pre-geological period of the earth development. They are interested in the internal, deep formation of the earth. As yet there is little information on these questions, but what there is is fragmentary and often hypothetical. For this reason, geologists are particularly interested in space study and research into other planets. Global processes of the earth development, such as the occurrence of envelopes on the earth's crust, tectonic movement and evolution of substances of the earth, can only be understood when there is close cooperation between geological and astronomical sciences, when they both benefit from information obtained by astronautics.

It seems to me that we, as geologists, in our geological concepts, do not look upon the earth as a part of the universe. Conclusions of cosmochemistry -- a science which is aimed at studying the composition of other heavenly bodies -- are still insufficiently used to understand the geological processes on earth. The concept of exogenous processes (those which take place in the surface sections of the earth's crust) are linked with solar radiation and processes occurring in the solar system. Now, we must determine the link between endogenous phenomena (causing volcanic eruptions, earthquakes, orogeny) with processes taking place in the universe as a whole. We, as geologists, realize even less the link between a substance on earth and one in the universe, and the role of a powdered meteoric matter in forming the earth's crust and even mineral deposits. When speaking of the

origin of substance on earth, we only think of our planet and do not take into account the material of the universe as a whole. In /20 the same way as when the Ptolemaic concept of the earth was completely changed to the harmonious study by Copernicus on the universe, now, we must understand that geological processes must not be limited only to our planet, and processes taking place on earth must be examined as a part of universal processes.

There recently appeared a work on the effect of meteoric matter on the metallogeny of the earth. It was suggested that global deposits of iron, manganese, copper and other metals at various times of the earth's geological history were possibly linked with a mass of substance of cosmic origin at a time when the earth crossed a meteorite shower. Several scientists are of the opinion that the earth, together with the Sun and other planets, revolving around the center of the galaxy, repeatedly crossed iron nebulae of the Milky Way and passed through them, apparently, several million years ago. Large masses of powdered meteoric iron could have settled on earth in the Pre-Cambrian period. Other, later periods of the earth's geological development, may have been suitable for the precipitation of manganese. Some scientists explain this by the large accumulations of manganese concretions on the beds of oceans (deposits from the Oligocene period). There is still much which is unclear in the suggestions, but they are very interesting and cause much speculation.

By investigating rock samples collected from the lunar surface, scientists discovered meteorite craters with a diameter of

approximately 0.5 mm. They were formed as a result of impact of micrometeorites traveling with a speed of more than 10 km/sec. The fact that these are micrometeorites and not "metal splashes" from larger meteorites is proved by the narrow boundary between the damaged and undamaged portions of the surface of specimens examined. It is possible that material from space also fell on the earth in past geological epochs. The fact that meteoric matter can burn out in earth's atmosphere still does not mean that it cannot reach the surface of our planet and help to form the earth's crust in individual ore concentrations. Special work in this direction will undoubtedly be of much interest for investigating the earth's crust.

Cosmogeochemistry -- is a science which is now being successfully developed. It must be aimed not only at studying the chemical compositon of other planets and bodies of the universe, but in recognizing the laws for formation of rocks and mineral deposits on earth. Here, one must start with the concept that substance on earth and in the universe is a part of a single whole -- matter in space. We now feel that the vast amount of material accumulated can be used for creating a hypothesis on the origin of the earth at the present level of knowledge by taking into account research in space. We still have little experience in using space research for geological purposes. Undoubtedly, as space technology, equipment and research methods are improved and later when space systems have been created specially for geological purposes, space geology will make considerable progress.

Manned long-term orbital stations will be very effective for geological study of the earth. They will provide continuous cosmo-geological information. We already know that when one section of the earth is repeatedly photographed (at different illuminance, humidity and with a different vegetation cover) there immediately appear new geological earth formation features. Long-term orbital stations will be a means for the simultaneous monitoring of very large regions of the planet, and this will be especially important to understand the physical and geographical processes when studying the effect of man on the forces of nature.

The number of geological and geophysical problems which can be /21
solved will gradually increase if geophysical, infrared radio location and radio thermal equipment is used in orbital space stations. Undoubtedly, in the future other means and methods of obtaining information from space will be used for geology, as for example, multi-spectral scanning systems operating in invisible ranges of the electromagnetic wave spectrum (radar, thermal and others). Magnetic survey of the earth from outer space will enable one to judge the overall nature of the planet's magnetic field, show the great anomalies and study the variations of the magnetic field.

Regional and global thermal anomalies can be established by using infrared photography. This material can provide information for studying the earth's thermal fluxes.

Radio location and radio thermal surveying will allow study to be made of the earth's surface, irrespective of weather conditions, and obtain additional geological information which is not given by photographs.

Geologists still rely on television and individual photographs from space obtained in passing with other information. Special space photographs which will help to solve many geological problems must be used.

Probably, it would be advisable to produce a special artificial earth satellite for geology, equipped for studying natural resources and carrying out global surveys from space.

Optimum photography levels must be developed and material obtained must be processed, a method and technology for space photography of the earth's surface and conversion of space photographs into photographic maps must be done, and one must study the possibilities for using geophysical observation methods from space and define the number of problems which must be solved by using them. Finally, a method for processing the information must be developed so that it may be used for the geological study of the earth. earth.

Each new phase in the conquest of space and each new launch of Soviet spacecraft is an important step in developing science of the earth and increasing the mineral and raw material potential of the USSR.

The Beginning of the Starry Way

A. Mrykin, Yu. Biryukov (TASS)

"Moskovskiy komsomolets", September 30, 1972.

In greeting the 50th anniversary of the formation of the USSR, we are justly proud of the fact that our country is responsible for

achievements in the development of rocket and space technology -- a complex branch which includes achievements in the modern scientific and technical revolution.

Rocket research in the USSR was widely developed in the post-war years. The key to the problem was the development of a powerful launch vehicle. A multi-stage ballistic missile was produced under the direction of F. P. Korolev. This laid down a firm foundation for the systematic venture into space.

Experience obtained in rocket research and the enormous capacity of the launch vehicle made it possible to design the first artificial earth satellites as quite complex systems which were reliable and very informative. Nevertheless, at first it was decided to launch a simple satellite (SS-1). They proceeded from the fact that a simple spherical shaped satellite would give data of braking caused by the upper layers of the atmosphere in the clearest form. There were other considerations also. Scientists /22 believed that the first satellite should have a shape close to that of natural heavenly bodies, since it would always remain the symbol of the beginning of mankind's space era.

October 4, 1957, when the first artificial earth satellite in the world was launched into space, went down in history. Science had obtained a new means of exploring extraterrestrial space.

The creation of the first manned spacecraft was another important achievement in Soviet astronautics. Yu. A. Gagarin's flight showed that man was no longer attached to his cradle -- the earth, and could live and work in space.

The first phase in the development of Soviet space vehicles was achieved by the flight of Vostok. One feature of it was the production of unique vehicles, launched individually for solving important scientific and technical problems, each one of which was the next stage in the USSR's space program. Another feature was that the launch boosters and the space vehicles were at that time developed by one team led by S. P. Korolev.

The second phase of Soviet astronautics began with the launch of the Kosmos-1 satellite according to a program laid down on March 16, 1962. This allowed for the significant increase in the number of launches of space research vehicles (in 1962 alone, 15 were launched, that is, as many as in the previous Five-Year plan).

Significant achievements by the Soviet Union during this phase were the first group flight of spacecraft, the flight of a female astronaut, the egress of a man into open space, a soft landing by an automatic station on the moon, the launch of an artificial lunar satellite, reaching Venus and the launch of heavy Proton and maneuvering Polyet satellites. During this phase, Soviet space technology began to serve the national economy directly, when the Molniya-1 communications satellite and the Meteor meteorological satellites gave palpable economic benefits.

The third phase in the development of Soviet astronautics began in 1969. Its main feature was automatic flights -- the transition to vehicles, active information robots, obtaining scientific information in interplanetary space and on the surface of the moon, Mars and Venus. The first of this generation of space

vehicles were the Luna-16 and Lunokhod-1. They are not overshadowed by the complexity of experiments carried out by Venus-8 which discovered the secret of surface rocks of the planet and Mars-2 and Mars-3 which became artificial satellites of Mars and landed on the planet in extremely difficult conditions during a dust storm.

The development of Soviet spacecraft is the result of the activity of numerous groups of Soviet scientists, engineers, technicians and workers collected into research and experimental and design teams. An important role among these was played by S. P. Korolev, an academician, who is reckoned to be the founder of practical astronautics.

One must also mention the contribution of G. N. Babakin, a corresponding member of the Academy of Sciences of the USSR, who directed the development of unique spacecraft for researching into the moon and planets of the solar system. Academician M. K. Yangel' also played a great part in the development of rocket and space technology. The design office directed for many years by A. M. Isayev, a doctor of technical sciences, developed the propulsion systems of the majority of Soviet spacecraft.

Rocket and space technology is one of the most complex branches /23
of our country's national economy. It requires enormous amounts of men and materials for development. Thanks to the support of the party, government and people, the USSR has become a great space power, and in 15 years has launched more than 640 spacecraft.

Soviet designers and scientists, by perfecting space technology, are making new strides in the conquest of space and attempting to use space research for the benefit of mankind.

IAF Awards to Soviet Space Researchers

TASS

"Pravda", June 21, 1972.

The Council of the International Aeronautical Federation (IAF) took place in Paris.

The Federation's Council decided to award the IAF honorary diploma to scientists, engineers and workers at the Soviet Astronaut Training Center for their contribution to the program for study and research of outer space.

The IAF's Yu. A. Gagarin gold medal was awarded to V. A. Shatalov and A. S. Yeliseyev, who have twice received the title of Hero of the Soviet Union, -- for their work in the complex and wide program of space research by manned spacecraft, which had great practical importance for setting up orbital stations and conducting a series of valuable scientific and technical experiments.

During the conference, the Council of the IAF unanimously decided to award the international diploma to the well-known Soviet scientist and academician, V. P. Glushko, for his contribution to the development of rocket technology and research into the physical and technical problems of power engineering.

Decisions taken by the IAF show the international recognition of the USSR's services to space study and research.

In the Name of Astronautics Pioneers

V. Belikov

"Izvestiya", August 30, 1972.

The Federation of Aviation Sports of the USSR have instituted a diploma im. space pilot Yu. A. Gagarin and a medal im. academician S. P. Korolev.

These two famous names are written on the first page of the chronicle of the space age. Yu. A. Gagarin, the first man in space, and the outstanding scientist, the designer of rocket and space systems, S. P. Korolev played a great role in the research and conquest of the universe.

"By recognizing their services in the development of astronautics, the Federation of Aviation Sports of the USSR decided to institute two new awards," -- said I. Borisenko, the secretary of the Commission for Sporting and Technical Problems in Astronautics. The Yu. A. Gagarin diploma will be awarded to scientists, designers, engineers and also teams and individuals who contribute to the development of rocket, space and aviation technology, aviation sports, and who work for the dissemination of aviation and space knowledge, or show high sporting achievements. The S. P. Korolev medal will be awarded to scientists, designers, engineers and space pilots of the USSR who, through their activity, help the /24

development of rocket and space technology and the practical use of the theoretical fundamentals of astronautics, and also those who advocate and disseminate scientific and technical achievements in space research.

According to this decision by the Federation of Aviation Sports of the USSR, the diploma and medal can be awarded to individuals of foreign countries for their success in the development of aviation and space technology, and those who hold world aviation and space records. The award of diplomas and medals will take place annually and will cooincide with the International Aviation and Astronautics Day on April 12, the All-Union Celebration -- Air Fleet Day of the USSR.

However, the award ceremony will take place at the beginning of October, the 15th anniversary of the launch of the first Soviet artificial earth satellite. A picture of this and also relief silhouettes of the Vostok rocket and the Soyuz spacecraft are on the reverse side of the S. P. Korolev medal.

To Space Explorers

TASS

"Izvestiya", October 4, 1972.

With respect to a decision by the office of the Federation of Aviation Sports of the USSR, a large number of scientists, designers, astronauts, public figures and journalists received the S. P. Korolev medal on the eve of the 15th anniversary of the

launch of the first artificial earth satellite by the Soviet Union.

These awards were given for the contribution to the development of aviation and astronautics, and the dissemination of the achievements of the Soviet Union in research and exploration of outer space and aviation technology.

The Yu. A. Gagarin diplomas were awarded to groups of scientists, designers, engineers and workers of the USSR, who participated in the designing, constructing and launching of manned and unmanned spacecraft, including the first artificial earth satellite.

The Tsiolkovskiy Gold Medal

TASS

"Pravda", October 20, 1972.

Yesterday the Presidium of the Academy of Sciences of the USSR awarded the K. E. Tsiolkovskiy gold medal for 1972 to academician M. V. Keldysh for his outstanding contribution to the scientific analysis of problems for studying and conquering outer space.

This award was instituted in 1954 and is conferred by the Academy of Sciences of the USSR for outstanding work in interplanetary services.

Liscovery by Astronauts and Scientists

"Aviatsiya i kosmonavtika", No. 4, 1972.

The Committee for Inventions and Discoveries attached to the Council of Ministers of the USSR has entered in the state register the discovery "The phenomenon of the vertical-beam structure of daytime radiation of the earth's upper atmosphere". The discovery /25 was made on the basis of analysis of results of visual observations from Soyuz-3, Soyuz-5, Soyuz-9 manned spacecraft.

The authors of the discovery are space pilots of the USSR, twice award winners of the Hero of the Soviet Union, G. Beregovoy and A. Nikolayev, Heroes of the Soviet Union, V. Sevast'yanov and Ye. Khrunov, and the Leningrad scientist, K. Kondrat'yev, a corresponding member of the Academy of Sciences of the USSR, A. Lazarev and M. Miroshnikov, doctors of technical sciences, A. Buznikov, a candidate of technical sciences, and O. Smoktiy, a candidate of physical and mathematical sciences.

During Soyuz flights the astronauts observed a global optical picture of the earth's atmosphere and its cloud cover and surface. When the spacecraft is in the earth's shadow a uniformly luminescent layer in the form of an ash-gray corona with a pink tint and of constant thickness is seen above the night horizon. The slightly diffuse upper boundary of this layer stands out sharply against the background of black space. When a star set beyond the earth's horizon Ye. Khrunov, during a flight of the Soyuz-5, was able to determine the height of the layer. It was 90-95 km. Once, directly

before sunrise, strong luminescence, in the form of columns going from the lower light strip near the horizon to an altitude approximately twice that of the night corona, was seen in the transition region between areas of the twilight corona and the night corona. This luminescence was observed close to the equator on the downward circuit of the orbit. Visually, the brightness of the column is slightly greater than that of the night corona. The color of the luminescent columns is a yellowish gray with a pink tint. When observing the column-shaped luminescence, it seemed as if powerful searchlight beams were directed upwards from the earth's surface. G. Beregovoy first saw this phenomenon.

During a Soyuz-9 flight, astronauts twice observed intensive luminescence lasting approximately seven minutes in the night side of the earth near the South Pole.

Observation material was used by Leningrad scientists, A. Buznikov, K. Kondrat'yev, A. Lazarev, M. Miroshnikov and O. Smoktiy, for compiling a single picture of the development of optical phenomena in the earth's atmosphere when it interacts with solar radiation. Joint analysis of these observations carried out by scientists and astronauts showed a vertical-beam structure of the daytime radiation of the earth's upper atmosphere during space twilight.

The authors of the discovery showed the sequency of development of optical phenomena in the earth's atmosphere. When a spacecraft is in the night side of the earth there is an ash-gray luminescent layer with a bright upper boundary in the shape of a

corona and a light strip near the horizon. As the spacecraft approaches the day side of the earth, the upper boundary of the night layer thickens and disperses. Then, space dawn appears with its characteristic color gamma near the horizon. The luminescent layer remains on the right and left side of the dawn, but sections of the corona in its direct vicinity are diffused and take on the form of thin luminescent filaments. The astronauts drew them in their flight log-books. Having carefully studied and analyzed visual observations, scientists came to the conclusion that there is a horizontal non-uniform day radiation of the earth's upper atmosphere.

When researching into the atmosphere from earth by using rockets and artificial satellites until now most attention has been paid to the altitude distribution of its parameters. For example, rocket probing made it possible to obtain the vertical dependence of the composition, temperature, pressure and optical characteristics of atmosphere to an altitude of approximately 500 km. /26 Photography and spectrophotometry of space dawn determined the vertical profiles of brightness in an altitude range of 45-500 km. The concept of horizontal uniformity of the optical properties of the lower layers of the atmosphere was also propagated to greater altitudes.

The vertical-beam structure observed by Soviet scientists and astronauts shows the existence of horizontal non-uniformity of radiation of the earth's upper atmosphere. This has a scientific and practical value when solving problems of an applied nature

concerning the energetics of the upper layer of the atmosphere and variations of its structural parameters. Studies f this phenomenon can be useful when determining the optical conditions for autonomous navigation and spacecraft orientation in near-earth paths. Visual observations of space-time parameters of the horizontal non-uniformity, with simultaneous experiments to study the spectra of horizontal non-uniformity, must be continued. This will enable us to explain the reasons for vertical-beam structure and study its seasonal and latitudinal changes.

I. SENTINELS OF SCIENCE

Satellites Serve Mankind

G. Petrov, Academician

"Izvestiya", March 15, 1972.

The basic feature of the Soviet space program is its sequence. /27 Each new phase of research is a logical continuation and development of the previous one. The first launch of the Soviet artificial earth satellites was a "test of strength" in discovering a new world. The processing of observation material of the movement of the first three satellites and measurement data gave interesting scientific results. The previously held concepts of near-earth outer space were considerably changed. At the same time, it was necessary to change from reconnaissance experiments to systematic, complex research and to in-depth analysis of various phenomena occurring in a natural "laboratory", which in fact near-earth space is, on such unprecedented scales, and their connection with processes on the Sun.

The question arose on the practical use of rocket and space technology achievements in the national economy, mainly for weather forecasting and communications. This task could not be carried out immediately. There were complex technical problems to be solved, for example, the building of meteorological satellites. There was also the need for specialized and complex experiments aimed at the

preparation and solution of the most complicated biological and technical problems for man in space. All these tasks were allotted to the numerous Kosmos vehicles.

Much scientific information had been obtained since Kosmos-1 was launched. In ten years much knowledge was obtained on the structure of the upper atmosphere, that is, the distribution of density, temperature and composition according to altitude, and also changes of these values. Theoretical suppositions on the dynamic nature of the upper atmosphere, especially changes of density depending on solar activity, were experimentally confirmed.

Comparison of results obtained by the third artificial satellite during maximum solar activity with observation of data on the movement of Kosmos satellites, showed that during half the solar activity cycle the average density at an altitude of 200 km was reduced by a factor of 2, and at an altitude of 300 km by not less than a factor of 3 1/2. Now, one can forecast the condition of the upper atmosphere during any phase of solar activity.

In 1958, by analyzing polar aurora processes, Soviet scientists showed that when these took place there was an intense warming-up, a "bulge" of the upper atmosphere. It must be said that at first this proposal was met with much skepticism. Now, there is no /28 longer any doubt. According to the results of analysis of satellite braking, the increase in particle density in regions where there are polar auroras at altitudes of approximately 300 km is several times greater than in lower latitudes. It appeared that

even weak geomagnetic disturbances have a global effect on temperature and density of the upper atmosphere. The relative effect of these disturbances is especially great when there is minimum solar activity.

At the present time, information obtained by satellites equipped with mass spectrometers allows us to talk quite definitely on the composition of the upper atmosphere. Whereas the basic component of atmosphere is nitrogen up to an altitude of 180-200 km, as the altitude increases there is a prevalence of atomic oxygen. Still higher, in years when there is minimum solar activity, from altitudes of 500-600 km and years when there is maximum activity -- from altitudes of 1,000-1,500 km, the atmosphere is a helium-hydrogen one.

Before direct measurement was done, on the basis of which one could calculate the temperatures of electrons and ions in the atmosphere, there were very contradictory views on their values. In particular, it was thought that there was a temperature balance between electron and ion components of the ionosphere. In fact this was not so.

The first direct measurement of ion temperature carried out in Kosmos showed that at daytime it was considerably lower than the electron.

Until quite recently, there were heated arguments on the very fact of the ionosphere's existence. Approximately ten years ago there was a much-discussed hypothesis on the presence of some hypothetic polar aurora which is constantly taking place in all

latitudes, and supports the night ionization of the atmosphere by supplementing the lack of solar ionization. Measurements done in several Kosmos showed quite convincingly that a particle flux, which is in fact observed in low and medium latitudes, is quite insufficient for this. Since the night ionosphere exists, this means that the speeds at which the ionosphere appears and disap pears are not as great as was supposed. Acccrdingly, the intensity of solar radiation responsible for ionization is now reckoned as being approximately ten times less than before. Apart from this, it was shown somewhat later that at night the ionosphere lifts, as it were, and ionization moves upwards.

Quite recently there was no doubt of the link between the earth's "constant" (main) magnetic field, determined by sources inside the terrestrial globe, and the "variable" magnetic field depending on the influence of external sources. The interconnection between these fields was especially obvious after Kosmos research. Data was obtained for the first time on the global distribution of magnitude and direction of the main geomagnetic field, and also information on the structure of the possible mechanisms of comparatively rapid changes of the earth's constant and variable field. Experiments conducted in outer space determined the degree of correspondence between the actual picture with theoretical models, based on observations on the earth's surface in the course of centuries. One important scientific result of this research is that, in fact, near the earth there are constant conditions which, as suggested, only appear during magnetic storms.

Who is interested in this information? Mainly, research into complex heat exchange and mass exchange processes in the upper atmosphere is important in practice.

Information on the structure and dynamics of the earth's upper atmosphere simplify the interpretation of experimental data on the atmospheres of other planets, and create a general theory of planetary atmospheres. /29

Automatic docking of artificial satellites in orbit and the controllable flight in the upper layers of the atmosphere require the knowledge of the change of atmospheric condition depending on the time of the year, local time, etc. Features of the outer ionosphere, that is, that region which can only be studied by rockets and satellites, are important for earth radio communications with space vehicles, radio communications between manned spacecraft and for using artificial satellites for radio communication and television systems.

Information on the magnetic field is widely used when prospecting for minerals, pilotage and aviation. However, magnetic plotting is an extremely labor-consuming task and requires much time. Maps, even when compiled with accurate and reliable measurements, after a certain time do not show the true distribution of the field. The great speeds of satellites, as it were, have reduced the dimensions of our planet. Electronic computers enable us to process a large amount of experimental data in a relatively short time.

Some Kosmos satellites were specially launched for researching cosmic rays. Much study has been made of our Sun. It is important that some characteristics of the Sun, especially those linked with solar activity, although inaccessible to study from earth, can be registered systematically. During periods when there is a sharp increase in solar activity there is a marked link between "earth" and "solar" phenomena. The better we can study this link, the better we shall be able to forecast the radiological situation on the flight time of astronauts. Information of this dependence is necessary in many other spheres of man's practical activity.

It must be said that experience gained during geophysical experiments in Kosmos satellites has been very valuable for developing and implementing the Meteor program. Kosmos satellites have become a basis on which the present meteorological system has been founded.

Kosmos satellites have also become a unique proving ground for space technology. For example, the Kosmos satellites first tested automatic docking methods in orbit. These experiments opened new horizons for creating complex space systems, and mainly for multi-purpose orbital stations.

The USSR is successfully implementing the space research program, successively passing from one important phase to the next. Space research will be continued with the same sequence and thoroughness and with detailed preparation for each new step, characteristic of Soviet science.

The Kosmos Program in Action

"Pravda", March 15, 1972.

Ten years ago, on March 16, 1962 the Kosmos-1 artificial earth satellite was sent into orbital flight. A new program was implemented for studying the upper layers of the atmosphere and near-earth outer space. Since then, almost 500 Kosmos satellites have been launched. Research carried out in satellites of this /30 series is shown in the conversation with scientists published below. At our "round table" is the director of the Scientific Research Institute of Nuclear Physics of the Moscow State University, academician S. N. Vernov, the director of the Institute of Physics of the Atmosphere of the Academy of Sciences of the USSR, Academician A. M. Obukhov, and the director of the Institute of Cosmophysical Research and Aeronomy of the Yakut Branch of the Siberian Department of the Academy of Sciences of the USSR, Doctor of Physican and Mathematical Sciences Yu. G. Shafer. Yu. Zaytsev conducts the conversation.

S. N. Vernov opens the conversation:

"Flights of the first artificial earth satellites and automatic interplanetary stations showed that we knew very little of the closest outer environment of our planet.

Before the satellites were launched many scientists did not even assume that the earth was surrounded by radiation belts. Even more unexpected was the discovery of solar wind -- as the continuous flow of plasma from the Sun was called. It appeared

that near-earth outer space is the arena of complex physical processes. The boundaries of the magnetosphere are changed by solar wind, the "population" of particles in radiation belts increases and decreases, the composition and density of the upper atmosphere changes, magnetic storms and polar auroras connected with them occur which interfere with radio communication.

It is obvious that these processes must not be examined in isolation. They can only be studied properly in close interconnection, mainly with different developments of solar activity. In this respect, Kosmos vehicles have given us unique opportunities.

Observations on the level of ionizing radiation were carried out by the first Kosmos satellites. This was necessary for establishing flight safety conditions for astronauts. Prolonged measurements made it possible to determine the permissible radiation doses depending on the altitude of the orbit, and geomagnetic and solar activity. On the basis of this information, scientists concluded that radiation safety could be guaranteed for future flights of Vostock and Voskhod spacecraft.

From the scientific point of view, this research is important to understand processes in the lower boundary of radiation belts, that is at altitudes of 200-400 km, especially in high latitudes. It is at these altitudes that interaction between charged particles and the earth's atmosphere occurs and they penetrate the ionosphere. The study of this interaction, determination of the lifetime of particles in dense atmospheric layers, and the dependence of their

behavior on geomagnetic disturbance is necessary to understand the structure and dynamics of radiation belts.

Let us take, for example, the problem of particle acceleration in outer space. This also occurs near the earth, on the Sun, in the heart of the galaxy, and obviously, beyond it. But when these "accelerators" are far from our planet, we only see the final result -- we see, for example, cosmic rays including those with great energy. However, we know little of the environment where particle acceleration occurs. Therefore, we cannot explain simply particle distribution of cosmic rays according to energy.

The picture is quite different in radiation belts. Due to the great amount of measurements made in them, we have sufficient information to answer the question how particles accelerate, how they change their trajectory and what phenomena accompany this. Furthermore, scientists can now forecast processes occurring in radiation belts. The question now arises how to use ideas and /31 theories developed for radiation belts to other areas of space -- the Sun and Galaxy."

Academician A. M. Obukhov speaks:

"Geophysics has also actively participated in the Kosmos research program. Mainly, I have in mind the whole research into properties of the earth's atmosphere along its whole layer. These experiments are directly linked with the problem of using artificial earth satellites for weather forecasting and also with questions of a general geophysical nature.

Naturally, launches of Kosmos satellites were made mainly for experimental purposes. One of the main tasks was to find new methods and means of collecting quantitative information on the earth's atmosphere, that is, those characteristics which can be expressed in numbers. These include radiation temperature, the amount of cloud covering the surface of the earth, and the size of individual clouds.

It has been possible to approach the problem of cloud "rating". The fact is that we show cloud elements on television pictures in a somewhat individual manner. We must give a quantitative characteristic not of each individual cloud, but of the whole cloud system. Such a system plays an important role in typifying weather. It was established that different cloud systems have a characteristic spatial distribution -- "a spectrum", that is, properties which can be fixed by recording earth and atmospheric radiations from satellites.

Soviet scientists were the first to carry out a global experiment for receiving thermal radio-frequency radiation of the earth and its atmosphere with the Kosmos-243 satellite. In particular, it was possible to compile a map of Antarctic ice, irrespective of whether its boundary was covered by clouds or not. The temperature distribution of the ocean throughout the whole world was also obtained.

Apart from this, by recording thermal radio-frequency radiation one can determine the moisture content in the atmosphere,

including water droplets in clouds, and detect the centers of intense precipitation hidden by large clouds.

Experience accumulated in the course of geophysical experiments on Kosmos was used for the actual development and implementation of the Meteor meteorological system."

Yu. G. Shafer, a Doctor of Physical and Mathematical Sciences, continues the conversation:

"Kosmos satellites play an important part in the scientific program for studying cosmic rays. Scientists at our institute participate in this research.

An artificial earth satellite has a specified time of active existence. Systematic observations normally require continuous measurement. Therefore, satellites identical in construction and with the same scientific equipment are used. They are put into near orbit in sequence at an interval of approximately six months. The next satellite is launched before the previous one has completed its calculated period in space. As a result, for a certain time they are at identical altitudes in the same latitudes. During this time their instruments are calibrated and the results of measurement are "stitched" together. In this way, one can carry out an experiment without breaks for a considerable time, and organize, as it were, a cosmic weather patrol. The reason behind this patrol is in expectation of a favorable concurrence of circumstances, when the natural laboratory itself will yield some interesting phenomenon which would be difficult or impossible to simulate on earth and obtain artificially.

We were interested, for example, in the question: On what /32
do changes in the average nuclear composition of cosmic radiation depend? It was suggested that there are moments when the Sun expels predominantly heavy nuclei. This theoretical supposition was confirmed when an actual event took place during a patrol search, and we observed it three times.

Research conducted by Kosmos satellites determined the periodic changes of the nuclear composition of cosmic radiation. The results were unexpected. Analysis of a great number of measurements showed that during years of minimum solar activity the average nuclear composition increased. Apparently, this is explained by the existence of interaction on the boundary of solar wind with the interstellar medium of the transient region, the density of which changes depending on solar activity.

The fact itself of the discovery of a transient region with a high concentration of radiation is remarkable. During a flight, shall we say, to Jupiter a spacecraft must cross it. Consequently, the design of such a spacecraft must provide protection from the effect of strong ionizing radiation."

Meeting Plasma Storms

Yu. Gal'perin

Doctor of Physical and Mathematical Sciences, Director of the Laboratory of Polar Auroras at the Space Research Institute of the Academy of Sciences of the USSR.
"Pravda" Press Department. Byulleten' dlya respublikanskikh gazet, No. 6, March 4, 1972.

Long before the first rockets and satellites were launched it was known that polar auroras are caused by charged particle fluxes entering the atmosphere -- electrons and protons with an energy from several hundreds of electron-volts to tens of kiloelectron-volts and above. This was established by ground observations of polar auroras, the study of their spectra, altitude measurement and research by photochemistry into processes occurring when this takes place. During polar auroras, at altitudes higher than 100 km, there is strong ionization of the atmosphere which considerably influences the propagation of radio waves. Since questions of radio communications are of primary importance, especially for arctic regions, where, to a great extent, they depend on the effects of polar auroras and magnetic storms, the study of processes linked with these occurrences has always attracted scientists' attention.

The range of work has been significantly increased with the arrival of the space age. The fact is that many effects linked with the interaction of high-energy charged particles on the upper atmosphere could only be studied with rockets and satellites. It is remarkable that the most significant part of the first great complex experiment in space, I mean the launch of the third Soviet

artificial earth satellite, was research into these high-energy charged particles in the upper atmosphere, and effects caused by them. A direct continuation of this work were the experiments conducted by the Kosmos satellites.

The program of the Kosmos satellites includes a whole range of study of high-energy particles. For example, there are high-energy particles linked with radiation belts and even higher energy particles of cosmic rays. Basically, we are interested in low-energy particles, that is, particles which cause polar auroras, and the ionization of the upper atmosphere, its warming-up, etc. The first Soviet satellites devoted entirely to the study of this problem were the Kosmos-3, and later the Kosmos-5 which was identical to it.

The satellites were launched with an angle of inclination of 49 degrees to the equatorial plane. In essence, this orbit did not allow us to carry out measurements directly in the area of polar auroras. We could only research the lower and medium latitudes /33 in detail. Therefore, the main attention during the experiments was paid to obtaining information on the formation of the ionosphere.

Another interesting aspect of the search conducted by these satellites was the study of photoelectrons -- superthermal particles with energy of tens and hundreds of electrons-volts. They occupy the intermediate position between electrons of "cold" plasma (of the ionosphere) and high-energy particles, and are the direct result of ionization -- the detachment of an electron from

a neutral atom. Data on their intensity were studied, and it was shown that photoelectrons can penetrate one hemisphere from another along magnetic lines of force.

A new phase in studying the nature of polar auroras was the launch of the Kosmos-261 satellite. The satellite's orbit was specially chosen so that its path regularly passed almost at a tangent along the polar aurora's zone. This significantly increased the amount of time spent by the recording equipment in the auroral atmosphere (from Aurora, the goddess of dawn, as all phenomena are called connected with polar auroras). Simultaneously, Kosmos-259 and Kosmos-262 satellites were operating at lower latitudes and measuring the intensity of hard radiation.

However, satellite measurement has a number of significant limitations. Owing to its great speed it crosses the area of space in which we are interested in a very short time. Hence, the satellite passes the polar aurora arc with a mean thickness of (approximately 10 km) in one or two seconds. Apart from this, owing to the earth's daily rotation the projection of the satellite's path is offset to the west with each revolution, that is, subsequent measurement is not done in the same place as the previous one. It is advisable to combine satellite measurement with simultaneous ground observations.

A complex experiment of this type was done by Kosmos-261 in December 1968. The satellite contained equipment for studying charged particles causing polar auroras, superthermal energy electrons, and also variations of density of the upper atmosphere

during auroras. Simultaneously, a network of ground geophysical stations filmed the polar auroras in the sky, recorded their brightness and altitude, determined several characteristics of invading active particles, and measured the temperature of the upper atmosphere. Observations were made at thirty ground points in the Soviet Union.

The launch of the Kosmos-261 satellite was the first joint space experiment conducted in accordance with the program for collaboration with socialist countries in the field of research and use of outer space for peaceful purposes. Many geophysical ground observatories and research institutes of socialist countries participated in the work. The experiment produced valuable results. We are glad that the help provided by colleagues from socialist countries was of use and, in many cases, even decisive.

Among these results there are effects obtained during joint research of a powerful chromospheric flare on the Sun during December 28, 1968. It happened when Europe was close to the midday meridian (11 AM Greenwich time). In this way, ground stations of socialist countries were in a very fortunate position for observing the flare. The Kosmos-261 satellite, at that time, was in the southern hemisphere near the area where the stations were positioned. As a result, it was possible to trace changes in the lower ionosphere linked with the hard X-ray radiation of the flare and in the middle ionosphere, caused by softer radiation.

The new information obtained is interesting and shows the movement of plasma in the ionosphere. It was known that after /34

midnight in northern latitudes near polar aurora zones the earth's ionosphere is very "devastated". Here, even at several hundreds of kilometers to the south of the aurora zone, radio communications are badly affected. This phenomenon was called the ionospheric "failure". Apparently, processes which preserve the night ionosphere stop working and, in particular, there is no upward lift of ionization.

Research showed that at this time specific variations of the magnetic field occur, which show the appearance of an electric current and a drift of an ionized component of the atmosphere. There is, as it were, an "evaporation" and "efflux" of the ionosphere.

The Kosmos-348 satellite continued the complex experiment begun by Kosmos-261. It was launched during the summer and it was possible to compare the geophysical conditions at various seasons. The satellite's equipment had been improved. Especially, it had been possible to increase the sensitivity of an instrument recording the spectrum of photoelectrons, that is, distributing them according to energy. It appeared that the spectrum obtained is very close to that calculated theoretically, but has some specific fracture which, obviously, is linked with ionization in that energy range.

In conclusion, one must not forget the Oreol satellite, launched in the program for Soviet-French cooperation in outer space research. To a great extent, it is a continuation of experiments conducted by the Kosmos-261 and Kosmos-348 satellites. The

Oreol satellite has more sophisticated equipment. Apart from measuring the characteristics of polar aurora particles, it carries out research into the ion composition of the upper atmosphere in polar regions. The analysis of the ion composition is linked with the discovery of the nature of "failures" in the ionosphere. The more elongated orbit of the Oreol satellite will give us a number of additional possibilities in this respect. The orbit's apogee is at an altitude of 2,500 km, that is, beyond the limits, so to speak, of the normal ionosphere. At these altitudes one can measure the characteristics of auroral particles until they interact with the earth's ionosphere.

We also hope to obtain new information on a specific, but very important phenomenon in nature -- the "hydrogen polar aurora" caused by the invasion of high-energy protons in the atmosphere, ascertain the basic characteristics of these protons, and compare results of measurements with theory.

Magnetic Measurement in Space

Sh. Sh. Dolginov

Candidate of Physical and Mathematical Sciences, Director of the Department of the Institute of Terrestrial Magnetism, the Ionosphere and Radio Wave Propagation of the Academy of Sciences, USSR. "Pravda" Press Department. Byulleten' dlya gorodskikh gazet, No. 10, March 24, 1972.

Lines of force of a magnetic field, stretching for tens of thousands of kilometers into outer space, determine the physical properties of near-earth space, the character of many processes

which occur in high atmospheric layers, and play an important role in the influence of corpuscular radiation on earth.

Information on magnetic declination is widely used for detecting minerals, pilotage and aviation. When artificial satellites were launched, the measurement of the magnetic field was done more quickly and over a considerably larger part of the earth's surface than was possible previously.

First research into the characteristics of the magnetic /35
field in near-earth outer space was carried out by the third Soviet artificial earth satellite. This was only done over the territory of the USSR. Nevertheless, as a result of this experiment, the first evaluations were obtained on the degree of convergence of various variations of the theoretical concepts of a field with the actual one. Information obtained showed it was possible to use a geomagnetic field in space technology -- for determining satellite orientation in absolute space.

The Kosmos satellites carried out experiments into the study of the magnetic field nearest to the earth. There were two basic tasks. The first -- research into the distributions of the main geomagnetic field with a source inside the earth, and measuring them over time. The second -- study of the variable effects in a magnetic field which are linked with magnetic activity, and the effect of solar corpuscular radiation.

The launch of Kosmos-26 and Kosmos-49 satellites resulted in the first magnetic measurements and covered 75% of the earth's

surface. A uniform survey accomplished in a short time showed a magnetic field free from secular variations and we could determine its distribution over an epoch of actual experiments. This information was used for compiling an international analytical model of the earth's magnetic field.

In 1970, the launch of Kosmos-321 allowed us to obtain a distribution of a magnetic field over 90% of the earth's surface. Comparison of measurements by this satellite with the two previous ones allowed us to determine with great accuracy the secular changes of a magnetic field over the whole surface.

The Kosmos-321 satellite was equipped with a quantum cesium magnetometer which carried out measurement every 2 sec. This provided interesting information on a number of questions on the variable magnetic field. In particular, the effect of the equatorial current jet in the plane of the magnetic equator on the daytime side was measured for the first time by satellite.

The equatorial current jet was first observed in 1922. However, after 50 years of various comprehensive research this phenomenon, to some extent, is still unexplained. Satellites research, combined with ground measurement, gives well-defined information for building a model of an electrojet.

The Kosmos-321 flight gave us interesting and important information on the mechanism of magnetic storms in polar regions. In particular, we were able to define the topology of magnetoactive zones in these regions. During one particularly intensive storm during March 8-10, 1972 the effects of polar electrojets were

measured. At the present time, this information is used for studying the earth's conduction.

The geomagnetic field played an important role in the Kosmos program. The majority of these space vehicles were equipped with special magnetometers for determining satellite orientation in absolute space by the earth's magnetic field. The Kosmos-215 had a magnetic damping system which decelerated the incoherent rotation of the vehicle's body around the center of masses.

It is worthy of note that artificial earth satellites not only increase the range of direct research, but also showed that they were a new means of experimentation in geophysics.

It was possible to achieve a high degree of measurement with satellites, and obtain by them new information on the features of /36
the distribution of the size and direction of the main magnetic field which are created by internal and constantly active external forces, and also new data on the morphology and possible mechanisms of relatively rapid changes of the main magnetic (constant) and variable earth fields.

500! The Satellite Is the Hero of the Day

Professor V. Mikhaylov

"Izvestiya", July 11, 1971.

The development of outer space has provided the Soviet Union with new impetus. The Kosmos satellites are a convincing example of the rational approach to solving problems in astronautics. In

essence, a whole range of scientific tasks in the Kosmos program was carried out mainly by using several types of unitized satellites.

Experience in building the first satellites for carrying out accual scientific experiments showed that the use of past achievements can significantly reduce the time for developing them and cut their cost. Therefore, it was decided to "circulate" the best rational solutions. A small unitized complex of auxiliary systems and instruments was developed mainly for satellites with different purposes. This included a radio telemetering system with storage, a radio command link, a radio monitoring device for orbit parameters, an on-board common time instrument, an altitude control system, power supply and temperature regulation. The overall utilization allowing satellites to be built on a production line basis, began with this auxiliary complex.

Three basic bypes of unitized satellites were built. The first was an unoriented satellite with chemical power supply for short-term scientific experiments. An unoriented satellite with a solar power supply, and oriented towards the Sun, was to be used for longer research. Apart from this, a "space arrow" satellite was built for conducting scientific experiments requiring accurate orientation towards earth in low near-circular orbits, and first aerogyroscopic orientation system in the world with aerodynamic stabilizers was used.

The body of the unitized satellites is a cylinder with hemispherical bases. It is divided into three compartments containing current sources, auxiliary equipment and scientific instruments. The solar batteries are placed on the body's surface and in the same place equipment and scientific

instrument sensors of all types depending on the experiment are attached outside on specially designed bars. Inside the pressurized body, containing instruments, there is a certain space for scientific equipment.

The body of the satellites is filled with a gas-heat carrier to ensure thermal conditions for on-board systems, and the surface has specific coefficients of absorption and reflection of external thermal fluxes. The lower hemisphere is a radiator and has louvers. If it becomes cool inside, the flaps of the louvers are rotated outside from the side with a cover which has a large absorption coefficient of solar radiation; if it becomes warm, on the other hand, they are rotated by the side with good heat emission.

The scientific instruments are controlled by programming and /37
timing devices and by a radio command link during communication sessions. A high-information radio telemetering system with a memory is used for recording and transmitting scientific information to ground measurement points. It can transmit information directly when conducting experiments, if the satellite is in the action zone of ground receiving points, or recording the results of measurement on the memory when it is outside of this zone.

Kosmos unitized satellites not only carried out experiments according to a program announced by TASS on March 16, 1962, but also according to a program of international cooperation for research and the use of outer space for peaceful purposes. For example, during Kosmos-261 and Kosmos-348 flights, designed for

geophysical research, many countries in the world carried out simultaneous observations with ground aids.

Leading institutes of the Academy of Sciences of the USSR and other departments are participating in suggesting and carrying out experiments in unitized satellites, as are research organizations of countries involved in the Interkosmos program.

A large amount of useful scientific information has been obtained by launching the Kosmos satellites.

Astronomy in Invisible Rays

"Nauka i zhizn'", No. 9, 1972.

This comparison will probably puzzle the reader. We are comparing air and armor: this almost weightless gas which a butterfly easily cuts with its wing and heavy plates which afford protection from destructive artillery shells.

The earth's atmosphere not only gives life, but as a reliable shield protects it, and insulates the earth from the lethal effect of outer space. Short-wave electromagnetic radiation from the Sun to earth can kill all life on earth. The atmosphere protects us from this. It has the same reliable protection as a three-feet thick layer of armor plate against ultraviolet, X-ray and gamma radiation.

Look at the diagram (Fig. 1). The radiation wavelength is set along the horizontal axis, the altitude above the earth's surface in kilometers along the vertical axis on the right, on the

left -- air pressure at a given altitude expressed in fractions of an atmosphere. The curve shows the altitude above sea level at which radiation arriving from space is attenuated by the upper atmospheric layers by a factor of 10.

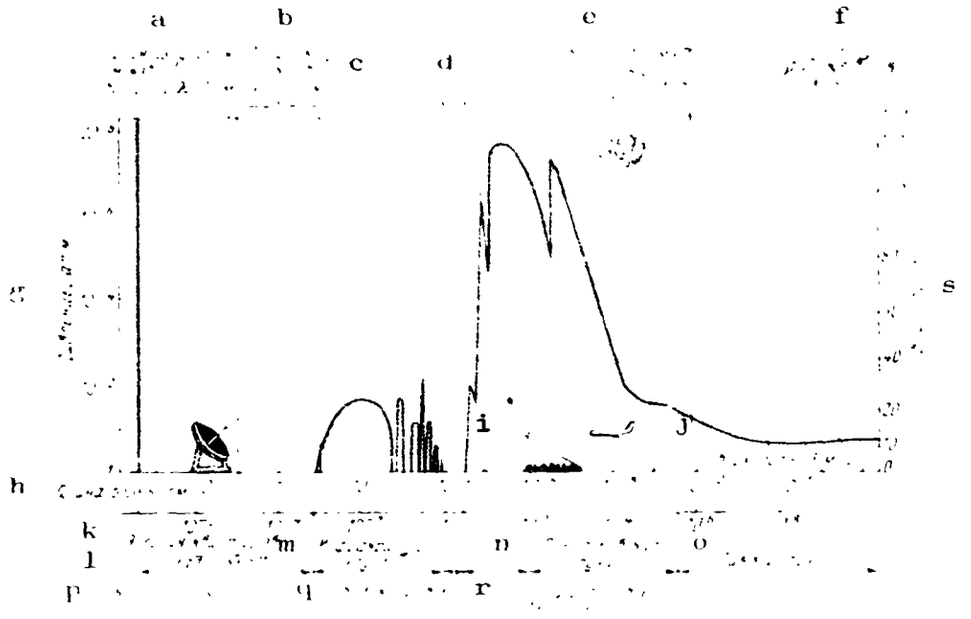

Fig. 1. The depth of penetration into the earth's atmosphere of electromagnetic radiation of different ranges arriving from space.

Key:
a. Radiation line of interstellar hydrogen λ = 21 cm
b. Relic radiation region
c. 100 μm
d. 1 μm
e. Electron-positron annihilation line E = 0.5 MeV
f. Maximum "pion" gamma quanta E = 70 MeV
g. Pressure, atmos
h. Wavelength, cm
i. Everest
j. Earth's surface
k. Quantum energy, eV
l. "Radio window"
m. Infrared radiation
n. X-rays
o. Gamma rays
p. Range of the spectrum
q. Visible light
r. Ultraviolet radiation
s. Altitude, km

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The scale of electromagnetic waves is divided into decades: the dividing lines here are waves, the length and frequencies of which have an even difference to a factor of 10. The quanta of the appropriate radiation also differ in energy to a factor of 10.

Twenty-three decades -- such is the width of the spectum of electromagnetic radiations, studied by modern science. Rays which are capable of passing through the earth's atmosphere (of course, in an attenuated form) constitute just over five decades. They belong to the visible and ultraviolet range of the spectrum and also to the centimeter-decimeter ranges.

Water vapors and carbon dioxide molecules are absorbed in the long-wave infrared and submillimeter range. Radiation in a range from 3,000 Å (1 Å = 10^{-8} cm) to approximately 1,800 Å is absorbed by atmospheric nitrogen, shorter than 1,800 Å -- by oxygen and /38 nitrogen molecules, and even shorter wave radiation by oxygen and nitrogen atoms.

A large part of the spectrum of electromagnetic waves is beyond the reach of telescopes set up on the bottom of the earth's atmosphere.

Over the past ten years, high-altitude balloons and rockets, artificial earth satellites and spacecraft have carried numerous physical instruments into the upper layers of the atmosphere and beyond it. Almost simultaneously, new directions of astronomic research have appeared: submillimeter, infrared, ultraviolet, X-ray and gamma astronomy. A new generation of astronomic instruments has appeared which are used for recording radiation in these ranges.

Research into space objects in electromagnetic wave ranges previously inaccessible have led to a number of fundamental discoveries. Our concepts of the world which surround us are being broadened and altered.

X-Ray Astronomy Is Ten Years Old

Professor S. Mandel'shtam

"Nauka i zhizn'", No. 9, 1972.

An Unexpected Discovery

This year we celebrate one of the newest directions in astronomy -- X-ray astronomy. These ten years have been marked by outstanding astronomical discoveries. This was said recently by V. L. Ginsberg, bearing in mind the number of equally important discoveries, the count for astronomy-physics for the ten years was 5:2 (astronomy: quasars, pulsars, "X-ray stars", relic radiation, space lasers; physics: the difference between electron and muonic neutrinos, the violation of the complementary principles of invarients) [1].

The discovery of X-ray "stars" and the space X-ray "background" /39 are the most important.

Since scientists now have at their disposal rockets and earth satellites able to carry measuring equipment beyond the limits of the earth's atmosphere, wide research has begun on studying heavenly bodies in wavelength ranges inaccessible to observations from the earth's surface, due to the absorbant effect of the earth's

atmosphere. In 1948 the X-ray radiation of the Sun was observed for the first time from a geophysical rocket at a height of approximately 100 km. This radiation is generated by the outer envelope of the heavenly body itself -- the solar corona. The temperature of the corona is approximately one million degrees. The excitation mechanism for X-ray radiation in the solar corona is basically thermal -- free electrons at high temperature, flying near atoms, ionize them, that is, detach the outer electrons and "excite" those that remain still bonded to the nucleus. These electrons, with a passage of time in the order of 10^{-4} sec, return to an "unexcited" state, radiating the photon of the specific frequency. The combination of these photons gives a bright-line component of the spectrum. When these flights are farther from the ions, the free fast electrons do not detach or "excite" the bond electrons, but only somewhat distort their trajectory in the ion electric field. Photons are also radiated, and these in combination give a continuous component of the spectrum called the braking radiation.

The density of matter in the corona is very small -- at the base of the corona it only contains about 10^8 particles per cubic centimeter (for comparison. the density of the earth's atmosphere at the base is 100 billion times greater). Therefore, the Sun's X-ray radiation flux is very weak in comparison with the overall flux of solar radiation: near the boundary of the earth's atmosphere, approximately 10^5 photons of radiation with a wavelength of 1-10 Å fall each second on an area of one square centimeter, which

in energy units is approximately 10^{-4} erg.cm^{-2}.sec^{-1}. (The full flux of electromagnetic radiation from the Sun near the boundary of the earth's atmosphere is $1.5 \cdot 10^{6}$ erg·cm^{-2}·sec^{-1}. Nevertheless, the registration of X-ray solar radiation is completely feasible by using modern radiation receivers -- photon counters (see below) with a window area of approximately one square centimeter.

Immediately after X-ray solar radiation was discovered, the question naturally arose: Are there still heavenly bodies emitting X-ray radiation and can they be observed? The answer was no. X-ray radiation from the nearest star, similar to our Sun, α Centaurus, which can have a hot corona and, consequently, emit X-rays, due to its great distance from the earth is, according to theoretical calculation, only 10^{-15} erg·cm^{-2}·sec^{-1} or 10 10^{-6} phot × cm^{-2}·sec^{-1}, which is practically invisible.

In the United States on July 18, 1962, Giacconi and Rossi and co-workers attempted to detect X-ray radiation of the moon by using X-ray photon counters on a geophysical rocket reaching an altitude of approximately 225 km. The attempt was unsuccessful; Lunar X-ray radiation was detected later by Soviet scientists, including the author of these lines, by using instruments on the lunar satellites Luna-10 and Luna-12 in 1966.

However, American scientists made an extremely important discovery: X-ray radiation was observed leaving space, the source of which was close to the center of our Galaxy. In subsequent experiments several groups of American scientists, also using photon counters in rockets, confirmed the existence of this X-ray

source and established that it was in the constellation of Scorpius, /40 at approximately 20° from the center of the galaxy. At the same time a second, somewhat weaker X-ray source, was discovered in the so-called Crab Nebula, and a diffuse -- covering the whole sky -- X-ray cosmic background.

In this way, X-ray astronomy was born. The discovery of the first X-ray source with a flux of approximately 10^{-7} erg·cm^{-2}·sec^{-1} or phot·cm^{-2}·sec^{-1}, and afterwards other powerful X-ray sources, was a scientific sensation. It was obvious that an outstanding discovery had been made -- new previously unknown heavenly bodies had been discovered.

X-Ray Stars and Galaxies

Thus, this year X-ray astronomy (nonsolar) is ten years old. As any other young child, X-ray astronomy has developed very quickly, giving much pleasure and disappointment to its excited parents -- physicists and astronomers. I intentionally put physicists first since, as in the case of radio astronomy, during the first period of its development, X-ray astronomy was more indebted to physicists than astronomers. This is explained since, obviously, physicists have a greater range of skills for successfully developing and testing new methods and equipment required during accumulating experimental facts than astronomers (the reader has probably guessed that the author of the article is a physicist).

At the moment, X-ray astronomy is a seething cauldron. There is a continuous flow of scientific articles describing new observations and new hypotheses, experimental information which has been obtained and immediately becomes obsolete, hypotheses are substituted by new ones, and fierce discussions arise at scientific conferences ...

What do we know today?

At the present time, about a hundred discrete X-ray sources are known. The strongest of them, as before, is the source in the Scorpius constellation Sco X-1. Later measurement for the X-ray radiation flux in the "classic" range of the spectrum 1-10 Å, more suitable for observations, was approximately 75 phot$\cdot$cm$^{-2}\cdot$sec^{-1}, which is $5\cdot10^{-7}$ erg$\cdot$cm$^{-2}\cdot$sec^{-1}. The next source of radiation flux is in the Crab Nebula Tau X-1 and is approximately 2.7 phot $\times$ cm$^{-2}\cdot$sec^{-1}. The weakest observed sources are approximately 0.03 phot$\cdot$cm$^{-2}\cdot$sec^{-1}, which is $2\cdot10^{-10}$ erg$\cdot$cm$^{-2}\cdot$sec^{-1}.

The majority of these observed sources are close to the plane of our Galaxy in the Milky Way and are concentrated in two groups with galactic longitudes of 315-40° and 60-120° near the constellations of Scorpius-Sagittarius and Cygnus-Cassiopeia. This corresponds to directions toward the two nearest spiral arms of our Galaxy. The "mean" distance from us to the stars in the first arm is approximately 82,000 light years, and in the second is half that distance. Hence, one can calculate that the

power of radiation of a "standard" galactic X-ray source in the range of waves 1-10Å is approximately 10^{37} erg·sec^{-1}, that is, 2,500 times the power radiated by our Sun in the whole wave band range (remember that only a 10 billionth fraction of complete solar radiation is required for a fraction of X-ray radiation). Proceeding from this statistically-based supposition on the number of possible "standard" X-ray sources in our Galaxy as being in the order of 100, we obtain a value in the order of 1 10^{39} erg·sec^{-1} in the X-ray range for the power of radiation of our Galaxy -- a typical spiral galaxy of average dimensions.

At the present time, apparently, there are approximately ten /41
known discrete sources outside of our Galaxy -- we shall call them extragalactic or metagalactic. These are sources, coinciding in direction with three radio galaxies: M-87 in the Virgo constellation, Centaurus-A and Cygnus-A, the brightest quasars 3C 273, the two so-called Seyfert galaxies -- NGC 4151 and NGC 1275, and also three sources in the Galaxy near us -- the so-called Large Magellanic cloud and one source -- in the Small Magellanic cloud. It is amazing that X-ray radiation flux of the M-87 radio galaxy (it is approximately 50 million light years from us) is approximately 10^{43} erg·sec^{-1}, which is 10,000 times greater than the X-ray radiation of our Galaxy and 70 times greater than that emitted by M-87 in the radio range. According to reasonable, statistically-founded calculations one can expect approximately 1,000 metagalactic X-ray sources.

X-Ray Telescopes

We must stress the following: in spite of the frightening power of X-ray radiation from sources shown at the end of the previous chapter, radiation flux arriving on earth (that is, the boundary of earth's atmosphere) is extremely small owing to the great distances to galactic and extragalactic sources. This creates exceptional experimental difficulties for X-ray astronomy. From the strongest (not counting the Sun) of known sources of X-ray radiation, Sco X-1, only approximately 75 phot·cm^{-2}·sec^{-1} arrive at the limits of the earth's atmosphere, and from a "standard" source approximately 0.1 phot·cm^{-2}·sec^{-1}. For comparison, let us show that approximately $2 \cdot 10^7$ phot·cm^{-2}·sec^{-1} reaches us from Sirius, the strongest star in the optical range, that is, 300,000 times greater than light photons. For the present, it is difficult and even impossible to determine the accurate coordinates of the majority of X-ray sources, their spectra, polarization and other characteristics required for the physical interpretation of their nature. I. S. Shklovskiy, a corresponding member of the Academy of Sciences of the USSR, recently carried out an interesting comparison. Accepting the sensitivity of modern X-ray radiation receivers as being 10^{-2} phot·cm^{-2}·sec^{-1}, we can now observe sources which are only 10^4 times weaker than the strongest source. In optical astronomy, with approximately the same detection sensitivity, using modern giant telescopes and photographing the sky with long exposures, one can observe stars which are 10^{10} times weaker

than Sirius in radio astronomy the corresponding interval is approximately 10^7 times. The number of objects which can be recorded with equipment of present-day sensitivity in order of magnitude for X-ray astronomy is 10^3, for optical astronomy -- 10^{10} and radio astronomy -- 10^6. It must be added that the spectral resolving power for X-ray astronomy today is only 10^{-1}-10^{-2}, for optical -- 10^{-4} and for radio astronomy -- 10^{-7}, and the angular resolving power is 1 angular min, 0.1 angular sec and 10^{-4} angular sec, respectively.

In this way, X-ray astronomy with its observation potential is still in the development stage and is inferior to optical and radio astronomy. Until today, counter telescopes (Fig. 2) have been mainly used for recording radiation in X-ray astronomy. Photons, passing through the input aperture, in the form of a thin /42 metal foil or organic film for X-rays, enter a chamber containing gas and cause ionization in it. The electrons which form are scattered by an electric field applied between the plate (cathode) and filament (anode), and cause an avalanche-like increase of electrons registered in the form a current impulse. These impulses are amplified with special amplifiers and are computed in the rocket or satellite. The number of recorded impulses during the exposure time is

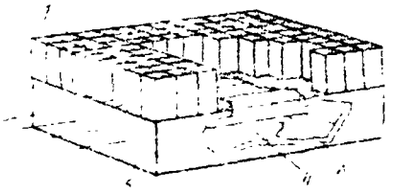

Fig. 2. An X-ray counter telescope. 1 - Collimator; 2 - Input aperture; 3 - Anode; 4 - Cathode; 5 - Photon counter

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transmitted by telemetry to earth. The area of the input aperture is several hundreds and even several thousands of square centimeters. The counter has several tens of anode filaments. A collimator limits the counter's field of vision, localizing the X-ray sources in the celestial sphere; for the most part, the field of vision of the collimator is several square degrees.

Telescopes are normally installed in a vertical rocket, the axis of the collimator is brought toward the required point of the celestial sphere by a gyrosystem, or slow scanning of specific areas of the celestial sphere is carried out.

In 1968 the USSR launched a special astronomic Kosmos satellite, and in 1970 the Uhuru special X-ray astronomic satellite was launched by the United States.

The sensitivity of the counter telescope, that is, the minimum observed photon flux, is determined as in all measurement systems by the "noise"-"background" level of the counter (more accurately, the value of the statistical fluctuations of the number of "background" pulses). The fact is that cosmic ray particles which penetrate the photon counters cause background pulses in them. Theoretical calculations show that the signal/noise ratio, determining the system's sensitivity, increases very slowly with the area of the counter aperture and the length of observation -- proportionately to the square root of the product of both values. In this way, it is technically very difficult to increase to any extent the sensitivity of counter telescopes by increasing the area of the counters or length of observation. However, there

is another method -- to collect X-ray radiation by special optics and guide it onto a small photon counter which, because of its small size, has little noise. Greatly elongated parabolic mirrors operating when there are glancing incidence rays can be used as optics for collecting X-rays.

The working area of the mirror of X-ray mirror telescope for glancing incidence is approximately 100 cm^2, the input aperture of the counter -- 1 cm^2. However, it must be noted that the use of mirror telescopes has limitations; apparently, it is difficult to replace telescopes for receiving hard radiation with a wavelength shorter than 10 Å.

What Do We Know of the Nature of X-Ray Stars and Galaxies? /43

Let us now return to discrete galactic sources. In spite of the relatively low degree of accuracy when determining their coordinates, it was possible to establish that six of them coincide in position with remnants of supernovae -- the Crab Nebula, Tycho Brahe, Cassiopeia-A, the Veil Nebula in Cygnus, Vela and Puppis. Sources of X-ray radiation of "old" remnants of supernovae example, the Veil Nebula in Cygnus, which exploded approximately 50,000 years ago, apparently, is the front of a shock wave with a gas temperature of 3-4 million degrees, spreading from the nucleus over a great distance.

The most interesting was the Crab Nebula -- a remnant of a supernova which exploded, according to Chinese chronicles, in 1054 and, as one of our famous astronomers said, due to its features

is the wet-nurse and bread-winner of many astronomers. The Crab Nebula did not "pump" in the X-ray range, it appears that it consists of a relatively extended envelope with a diameter of 1-2 angular minutes in comparison with soft X-ray radiation from a small nucleus, known earlier as the star of the 16th magnitude giving radio-, optical and X-ray pulsars with a period of 0.033 sec. X-ray radiation of the Crab Nebula and, by the way, its radiation in radio- and optical ranges is not thermal (as, for example, the radio-, optical and X-ray solar radiation) -- it is caused by the radiation of free electrons emitted by a nucleus with speeds close to the speed of light, in a strong magnetic field (the so-called synchrotron radiation).

In the remaining remnant of supernovae listed above pulsars were not observed. However, four more pulsars were observed among other X-ray stars recently. One of them lies in the area of the Crab Nebula -- its period is 3.8266 sec; apparently, it coincides with NP0527 radiopulsar. X-ray pulsars Cyg X-1, Cen X-3 in the constellation of Hercules also have both fast periodic changes of radiation flux, characteristic of pulsars, and slower changes with a period of several days. This forces one to assume that we are observing dual systems, consisting of two stars, revolving around a common center of gravity, of which one star is really the X-ray pulsar. Periodic obscuring of this star when it passes behind the the second star also causes slow changes of brightness.

The remnants of supernovae are extended sources, and as for "intermittent" sources, as was said earlier, the accuracy for

determining the coordinates of X-ray sources on the celestial sphere is small and, therefore, it is very difficult to identify such sources with known optical or radio stars or, on the contrary, confirm that the specific X-ray source does not coincide with any optical or radio source. At present, exceptions are strong sources Sco X-1 and Cyg X-2, the position of which was determined by using a special attachment, a so-called gauze collimator; the first had an accuracy of approximately 1 angular minute, and the second of approximately 10 angular minutes. The X-ray source Sco X-1 can be identified with sufficient reliability with a blue star of the 13th magnitude. This star has variable optical radiation over time -- relatively fast scintillation and slower changes of brightness -- and, apparently, is a dual star. Similar rapid scintillation with a period of approximately 10 min and slower changes of brightness were also observed in Sco X-1 X-ray radiation. Sco X-1 /44 is a very compact plasma formation with a diameter in the order of 10.000 km and a density of approximately 10^{16} particles per cubic centimeter, and has a temperature of approximately 50 million degrees. This plasma cloud, due to the loss of energy by radiation, could have only existed for an order of a second. How energy is "pumped" in Sco X-1, for the present, remains unclear.

The situation with Cyg X-2 is even more complex. Several hundred stars are contained in a rectangle of the possible error for determining the position of the X-ray source. The most likely candidate is also the "blue" star of the 15th magnitude, probably

a dual, with rapidly changing brightness. Whether the Cyg X-2 belongs to the same class of ojects as Sco X-1 or is another type of star is not yet clear.

From what has been said, it follows that one of the main problems of observation X-ray astronomy today is to learn to determine the coordinates of local sources with an accuracy sufficient enough, more or less, for reliable comparison with optical and radio stars.

If we now return to extragalactic sources, of which we spoke earlier, once again the mechanism of X-ray radiation, to a considerable extent, is unclear.

One interesting fact attracted attention when the nature of extragalactic X-ray sources was being analyzed. The appearance of supernovae is a relatively rare phenomenon; in our Galaxy these stars are observed optically, on an average, once every several hundred years. If one takes the total number of galaxies close to our Galaxy, for example, at a distance of 30-50 million light years, the number of such phenomena will be sufficiently large enough to notice the appearance of a supernova once every several months. Young supernovae two or three months old, emitting a X-ray flux in the order of 10^{42}-10^{43} erg·sec^{-1}, give a X-ray flux on the boundary of the earth's atmosphere of approximately 10^{-10} erg·cm^{-2}·sec^{-1}, that is, sufficient to be observed. Apparently, such explosions have been observed twice: the Cen X-2 source, first observed in 1967, quickly reached a brightness comparable

with that of Sco X-1, and then quickly disappeared; in a similar way, the Cen X-4 source, first observed on July 6 and 9 1969, reached a brightness 2.5 times greater than that of Sco X-1 and then faded relatively slowly, and on September 24 was no longer visible.

X-Ray Background and the Future of the Universe

As was said above, apart from discrete galactic and metagalactic X-ray sources diffuse cosmic X-ray "background" is observed -- the whole universe is weakly illuminated by X-rays. Perhaps, this background is the greatest riddle and causes theorists most trouble when interpreting the nature of it. The background was experimentally studied in an extremely wide spectral interval -- from super-soft X-ray radiation, with a wavelength of 50 Å, to hard gamma radiation with a wavelength of 10^{-4} Å[1]. The absolute value of the flux from the diffuse background is very small.

Undoubtedly, the greatest part of the diffuse background has /45 an extragalactic nature. This follows since the radiation flux for wavelengths shorter than 1 Å, not absorbed in interstellar gas in our Galaxy, is isotropic -- a radiation flux in limits of ±10% does not depend on the galactic latitude; the flux is reduced in

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1 In experiments mentioned above for measuring the X-ray radiation of the moon from a lunar satellite, measurement of the diffuse background in a soft region of the spectrum of 8-14 Å was done and was a record for that time. These measurements were important because observation of the X-ray background was carried out for the first time far beyond the limits of the earth's atmosphere, which prevented any processes in the remaining upper layers of the earth's atmosphere from playing any role in the formation of the background.

very soft radiation when approaching the plane of the Galaxy, when, owing to the "flattened" shape of the Galaxy, photons in interstellar gas must travel greater distances than in other directions.

Several suppositions exist on the nature of the diffuse background. At first glance, it is most natural to assume that the background is caused by the total X-ray radiation of all galaxies within the universe. However, calculations show that the estimate of normal galaxies, such as our Galaxy in the universe, gives a value two orders smaller than the observed. The estimate of radio galaxies of the Centaurus-A and Virgo-A (M-87) type and also 3C 273 quasars and pulsars of the Crab Nebula type is of little help. In this way, if one does not assume the existence of extremely powerful metagalactic sources of X-ray radiation still unknown, the hypothesis that the diffuse background is formed by radiation of spacially unseparated sources is not confirmed. There are other hypotheses, but spatially however, they all meet with serious difficulties.

Nor do we understand how very soft radiation "breaks through" to us: radiation with a wavelength in the order of 50 Å must be practically completely absorbed in our Galaxy's interstellar gas.

However, the most interesting question is this. There is reason to assume, more or less, that thermal radiation of intergalactic gas contributes most to the diffuse background. In principle, one can determine the temperature and density of the gas according to this radiation. At the present time, evaluations of the temperature fluctuate between 300,000 and 300 million degrees,

and evaluations of density between 3 and 10 particles per cubic meter.

The density of intergalactic gas is very important in cosmology. As is known, the fact is our universe has been expanding over the last 10 million years. Modern theoretical cosmology suggests two possibilities: the so-called "open model" of the universe, when its expansion will continue in the future, and the "closed model" , when the universe will begin to compress in about 10 billion years' time. In fact, such a model is feasible and depends on the average density of matter in the universe. If it is less than a certain critical density, an open model results, and if greater, a closed model. The latest calculations give the critical density close to three particles per cubic meter.

However, the calculations shown above, for the density of matter in the universe according to the diffuse X-ray background, are based on such uncertain experimental data that it is impossible at the present time to give a simple conclusion on the model of our universe. However, we still have sufficient time to tell our readers what awaits us -- the further expansion of the universe or its "collapse".

X-Ray Observatories in Space

All the results shown above were obtained by equipment in rockets and earth satellites (aerostats were sometimes used for research into hard X-ray radiation), when the length of observation of each source did not exceed tens of seconds or one or two

minutes. As was said, the equipment's sensitivity to weak radiation fluxes can be increased by lengthening the duration of observations. /46 The setting up of an X-ray telescope on the moon is the most promising and is technically feasible in the near future. The first experiment in operating a small counter telescope at the Physics Institute im. P. N. Lebedev of the Academy of Sciences of the USSR, which worked for several months on the Lunokhod-1, made it possible to obtain the necessary information for building such telescopes, and, in particular, show the measures required to enable them to "survive" in the rigorous conditions of lunar night. Large counter and reflecting telescopes for glancing incidence, set up on the moon, can be directed at the required point of the celestial sphere by commands from earth, and hold the examined X-ray source in their field of vision for many hours and days by using special optical stellar guides. The information obtained will be recorded in memories and transmitted back to earth during communication sessions. One great advantage of an observatory on the moon is the fact that there are no radiation belts here which interfere with X-ray observations in near-earth orbit.

New possibilities for extra-atmospheric astronomy and, in particular, for X-ray astronomy are possible with the appearance of manned long-term orbital stations of the Salyut type in the USSR, and "celestial laboratories" which are to be launched in the USA. Automatic control units play a large role in space research. However, man's role cannot be overestimated. When one is

investigating the unknown, each subsequent operation from the numerous operations required in astronomical observation must be selected carefully, based on analysis of results of previous measurement: sometimes, one must repeat one or several measurements, sometimes change the parameters of the instrument, its sensitivity or resolving powers, etc. It is impossible to program this sequence of operations, and extremely difficult to control instruments from earth. Valuable research can only be done by man -- an astronaut in a spacecraft with high technical qualifications and thorough technical knowledge. In the near future it will be technically possible to send into space large counter telescopes with an aperature area of several square meters, and reflecting telescopes for glancing incidence with a diameter of approximately a meter, and a length of 5-6 meters which can be controlled by man. It will be possible to observe with these instruments, for example, objects of the Sco X-1 type in the nearest galaxies by increasing the distance we penetrate the universe by several tens of times. An astronaut orienting a spacecraft will direct the telescope at the object to be examined or at the necessary point of the celestial sphere, then hold the object in the field of vision with an autonomous guidance system with an accuracy of several seconds by "optical" stars. By using special electronic and optical cameras, the astronaut will photograph sections of the celestial sphere in X-ray and visible rays for determining accurately the coordinates of X-ray sources, and linking them with "optical" sources and

studying the structure of elongated X-ray sources. Radiation spectra can be studied by spectrometers, radiation time characteristics (pulsation, scintillation and explosion) by photometers, and radiation polarization by using polarimeters. Long-term manned orbital stations containing many instruments controlled by man, combined with lunar observatories, will give X-ray astronomy regularity, production and precision of observations, which are now peculiar to ground optical and radio astronomy.

Prospects for Extra-Atmospheric Astronomic Research

V. G. Kurt

Doctor of Physical and Mathematical Sciences
"Priroda", No. 5, 1972.

In the middle of the last century, the French philosopher and /47
positivist, Auguste Comte, maintained that the chemical composition of stars, in principal, would never be determined by man. However, ten years after Comte's lecture spectral analysis was created, whereby it was possible to determine the chemical composition of stars. Spectroscopy rapidly earned its place in astronomy, not only for determining the chemical composition, but also researching into many physical properties of stars, planets, galaxies and other celestial objects. Nevertheless, Comte's followers would have said that all types of radiation would be inaccessible to us if they did not penetrate the atmosphere. Only a minute fraction of the almost limitless electromagnetic spectrum reaches the earth's surface.

The space age has meant a revolution in astronomy -- the appearance of all-band astronomy. Completely new equipment is required to perceive waves in X-ray, submillimeter and other ranges. Optical astronomy, going into space, meets new difficulties. This article is devoted to all these questions.

What Interferes with Ground Observations?

All theoretical building of astronomy -- from the movement of planets suggested by Ptolemy, to modern cosmology -- is based on observations. As means of observations developed, astronomy mastered the whole accessible range of the electromagnetic spectrum. Radiation reaches the earth's surface through two transmission windows: the optical, extending from 3,000 Å to 1-2 μm, and the radio window in a wavelength band from several millimeters to 10-30 m. Before the end of the 40's, all observations were done in the optical band, and the radio window has only been used for the last 20 years.

Where in the atmosphere is the absorbent "screen" which holds back the remaining electromagnetic radiation? Ultraviolet radiation (λ = 3,000-1,800 Å) is absorbed by ozone at altitudes of 30-70 km, by molecular oxygen at altitudes less than 120 km (λ = 1,800-1,000 Å), and by atomic oxygen and nitrogen at altitudes up to 200 km (λ < 1,000 Å). Above 100 km the atmosphere is very thin but is sufficient to completely absorb X-ray radiation. The situation is somewhat different in the infrared region where radiation is absorbed by nitrogen, water vapor and carbon dioxide molecules

which accumulate at relatively low altitudes. Due to this, individual areas of the infrared region can be observed from "aircraft" (10-20 km) or "aerostat" (20-40 km) altitudes. Great altitudes are required for researching into submillimeter waves which lie between the far infrared and radio region of the spectrum.

Long-waves cosmic radio radiation is reflected by the ionosphere which extends for a great distance from the earth. One must take equipment to an altitude of 10,000 km and above to research into kilometer waves. This situation is shown visually in Fig. 3, where a curve corresponds to an altitude at which radiation is attenuated e times[2].

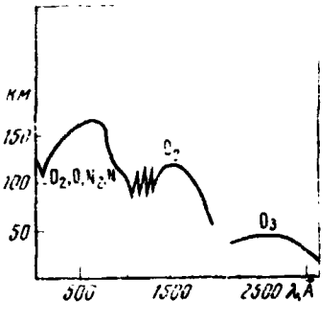

Fig. 3. Radiation transmission by the earth's atmosphere in ultraviolet and X-ray regions of the spectrum. The Y-axis the the altitude to which radiation of a given wavel ngth penetrates; the curve shows atoms and molecules absorbing radiation.

Selective absorption by the atmosphere is not the only main limitation for ground telescopic observations. A second limitation is caused by atmospheric turbulence which, as a rule, does not allow one to obtain a resolution better than 0".5 - 1". The latter causes a reduction in the penetrating power and resolving power of telescopes. For example, the extreme working stellar magnitude, at which one can still fix objects of a certain brightness, is 23^m, and the spatial resolution for the moon is 1 km, for Mars /48

2 e -- is the base of natural logarithms equal to 2.7182...

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-- 150 km. Effects caused by turbulence of the atmosphere are especially felt when large instruments with a mirror diameter greater than 2-3 m are being operated (Fig. 4). Therefore, astronomers are carefully looking for spots with the best astroclimate for testing the capabilities of large telescopes. In the next ten years approximately ten telescopes with a diameter of 2-4 m will be introduced in places where the dimension of a star image quite often is less than 0".5. However, these difficulties will completely disappear if one sends a telescope in a rocket or satellite beyond the limits of the atmosphere -- that is, produce a space telescope.

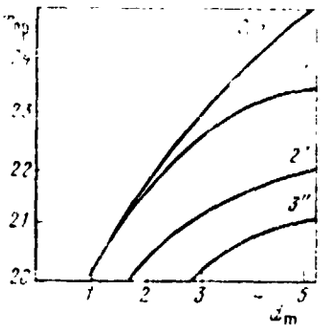

Fig. 4. Dependence on the extreme fixed stellar magnitude m_{ext} on the telescope diameter (on the x-axis) and angular diameters of the disc image of the star (figures above the curves). All the curves are drawn for a constant focal telescope distance. Key: a. m_{ext}.

Requirements of a Space Telescope

Analysis of the possibility of using large space telescopes must be done after studying those of earth instruments. Of course, the cost of a large orbital telescope is 10-100 times greater than that of a similar earth instrument, which must be taken into account when planning future experiments. At the same time, there are no basic difficulties which prevent one, during the next 10-20 years, from putting into near-earth orbit or even setting up on the moon, a large optical telescope with a diameter of up to 3 m (Fig. 5).

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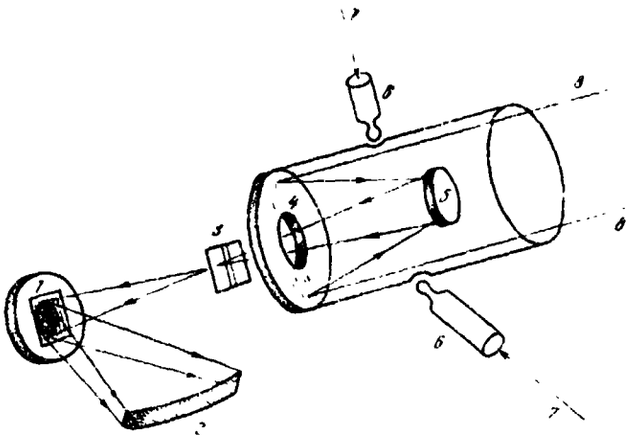

Fig. 5. An optical diagram of an orbital telescope equipped with a defraction spectrograph. 1 - Defraction grating; 2 - Spectrum of star; 3 - Spectrometer aperture; 4 - Main mirror; 5 - Secondary mirror; 6 - Orientation telescopes; 7 - Rays from navigational stars; 8 - Rays from researched star.

In principle, such a telescope can operate in a spectral range from 800 Å (and perhaps in an even shorter wave) to wavelengths of approximately 1 mm.

Requirements for the mirror of a space telescope need not differ from those required today of the best ground telescopes. In theory, this mirror can have in the center of its field of vision an angular resolving power determined by defraction and equaling λ/D^3, which for λ = 1,000 Å is 0".006. This means that one could see a five-kopek coin at a distance of 500 km through such a telescope. Of course, the present level of technology cannot produce the required quality of surface preparation for this, since the production of a mirror with a diameter of up to 2 m with a resolving power of 0".2 is still beyond our capabilities. One must remember that the mirror of an orbital telescope will work in weightlessness, although it was built on the ground. The true discharge of a mirror and

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3 Here, λ is the wavelength, D is the mirror diameter. If both these are measured in centimeters, the limit of the angular resolving power will be obtained in radians. To convert it into seconds of arc the number obtained must be multiplied by 206,265.

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methods for checking the mirror surface, which are continually being developed, will produce a resolving power of 0".1. I am intentionally omitting to mention the temperature conditions of a mirror, since this is a purely technical question. In principle, any required degree of stability is feasible. Apart from this, there is no doubt that the mirror of an orbital telescope must be made from sitall, a substance with a very small (practically zero) coefficient of thermal expansion.

It is obvious that the accuracy of the altitude control system and stabilization of such a telescope must correspond with its resolving power or exceed it, that is, must equal 0".03-0".1. By itself such an accuracy cannot be accomplished, if guidance is done by an examined star-like object, there still remains the problem of temperature deformation and warping of the telescope components (Fig. 6). However, one can assume that an accuracy of 0".1 will be achieved in the near future in automatic unmanned stations specially designed for astronomical observations.

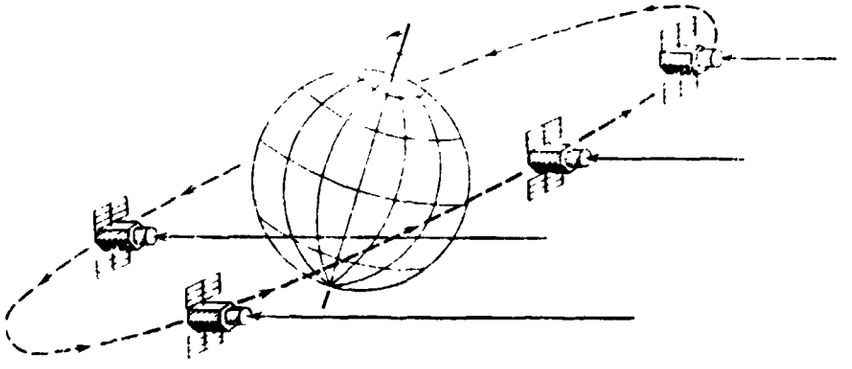

Fig. 6. The movement of a space observatory in near-ground orbit; the orientation of the telescope is kept constant towards the star being investigated.

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Let us examine the penetrating power of a three-meter space telescope, starting with a brightness background of ~5^m per square degree. With flux from a star equal to that from the background we obtain a value for the extreme fixed stellar magnitude $+27^m$, and with a resolving power equal to 0".2, one notices a contrast of only 10% and even $+29^m$. Flux from a star $+29^m$ in the visible range is 10^{-5} phot·cm^{-2}·sec^{-2}, or $2.5 \cdot 10^{-9}$ phot·cm^{-2}·sec^{-1} Å for the maximum of the spectrum. The mirror will collect from the star on a detector 0.6 phot·sec^{-1}. If the detector gives one pulse for ten incident photons, we obtain 0.06 pulses/sec. It is obvious that such an object can only be recorded with a large accumulation time of pulses, and spectral research of it is practically impos- /50
sible. During photographic recording the accumulation time must be approximately 200 hours. In this way, by actually evaluating the possibilities of a three-meter telescope we find that a scarcely discernible object in the sky must be no weaker than 25^m. Such a star can be recorded by electrophotometry for a time of 100-1,000 sec with an error not exceeding 10%, and photographed with an exposure in the order of several hours.

If during observations outside the atmosphere there would be no sky background, that is, a star or galaxy would be observed on an absolutely black sky with a detector not having inherent noise, the detection limit would only be determined by the observation time. For actual detectors with a dark background of 10-100 pulse/sec, the extreme stellar magnitude will be 25^m, and when there is

a sky background determined by zodiacal light and a background of weak, indiscernible stars and galaxies, it could be 1-2^m worse. In this way, the expected gain, in comparison with the best telescope situated in a position with ideal astroclimate, is scarcely greater than 1-2^m. It will still be impossible to detect with such an instrument, for example, planets revolving around the nearest stars, since their stellar magnitude fron a distance of 10 light years is +30^m with an angular range from the star of 0".3-1".5. As for the resolution of planet details in the solar system, it increases by 5-10 times and for the moon reaches 10-200 m, and for Mars 15-30 km. It must be noted that much better resolution has bee obtained for these heavenly bodies by interplanetary stations equipped with phototelevision equipment, however, interplanetary stations have not been sent towards other planets of the solar system, and a space telescope will not compete for resolving individual details on their visible surface[4].

Spectral and Photometric Research

There is an impression that the main task of future extra-atmospheric telescopes will be spectral and photometric research in the ultraviolet, infrared and submillimeter regions of the spectrum. In this research the resolving power of a telescope is not so essential if it is better than 1". However, research into the structure of weak galaxies, quasars, etc., is extremely interesting at a resolution of 0".1.

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4 For example, photographs were obtained of Mars with a resolution of better than 1 km.

Photometers for all regions of the spectrum, photographic material for visible and ultraviolet regions and television equipment for all regions apart from the submillimeter, will be used for collecting information from such a telescope. The best method is the use of photoelectric detectors for ultraviolet and visible regions, photoelectric multipliers and electronic and optical transducer tubes where an efficiency of 0.3 of a pulse on a photon has been achieved on a dark background of 1 pulse/sec. Therefore, there must be joint efforts to improve detectors in the infrared and submillimeter ranges. Normally, these detectors require cooling, sometimes even to a temperature of liquid helium (4° K), and their sensitivity is much less than the maximum one. But in one ultraviolet region alone the number of objects observed by a three-meter telescope is practically inexhaustible. An American orbital astronomical observatory (OAO), equipped with telescopes with a diameter of up to 40 cm, has obtained information for 10,000 stars in the ultraviolet region of the spectrum. /51

Obviously, the launch into orbit of a two- or three-meter telescope will be preceded by launches of telescopes with a diameter of 1-1.5 m in type OAO vehicles equipped mainly with spectrometers and photometers for the near-ultraviolet region (1,000-3,000 Å).

Equipment for the X-Ray Band

Let us turn now to the X-ray wavelength band extending from 0.1 to 100 Å, which corresponds to quantum energy of

100-0.1 kiloelectron volts. Gas-filled proportional counters with a thin beryllium window (up to 100 μm) or organic film with a thickness of 10-1 μm (mylar, formvar, polypropylene, polycarbonate, etc.) have a monopoly in this region. Results have already been published, obtained during the launch of a counter with a dimension of 1 × 1 m, however, there is a predominance of counters with an area of approximately 1,000 cm^2. Until now, the main results in the X-ray region of the spectrum were obtained by rockets at altitudes of 100-200 km, and the length of each experiment was 5 min. However, it appears that this situation will soon change. The first satellite equipped for X-ray radiation research, the Uhuru (USA), has already led to interesting discoveries. Up to the present time, more than 50 discrete X-ray scurces have been observed, of which only about 15 have been identified with known optical objects. These are the remnants of the explosions of nova, diffuse nebula, remnants of supernova, the 3C 273 quasar, Magellanic clouds and the Seyfert galaxy. The class of X-ray object does not coincide with radio sources and is a special group of objects with different radiation mechanisms: thermal irradiation of plasma, heated to millions of degrees; synchrotron radiation of relativistic electrons in magnetic fields; an inverse Compton effect of electrons in infrared photons, etc.

There is extremely interesting research into the isotropic X-ray background [2], the nature of which is still not fully explained. It is possible that the background can be explained

by several independent mechanisms, each of which dominates one or other region of the spectrum. This may be so: thermal radiation of an intergalactic gas at a temperature of 10^6 °K and a density near to the critical ($2 \cdot 10^{-29}$ g/cm^3); the decay of π^0-mesons; the inverse Compton effect of relativistic electrons in quanta of relic submillimeter radiation which has remained from previous stages of development of the universe.

At the present time, sources with a flux intensity (in the region of 2-8 Å) 10^{-2}-10^{-3} quantum$\cdot$cm$^{-2}\cdot$sec^{-1}, can be observed in the X-ray range. Normally, a proportional counter can simultaneously determine the flux from a source, its spectrum, the position of the source in the sky and the angular dimension. The spectral resolving power of proportional counters is small: in the 2-8 Å range is 15-20%, decreasing by five times for 50 Å, since the spectrum of sources is only determined approximately. In conjunction with a cellular collimator, counters can determine the position in the sky and the angular dimension of sources with an accuracy of approximately one degree, however, a modulation collimator gives a determination accuracy of up to 20", it is true only in the very brightest sources of the Scorpius XR-1 type with a flux of 20-1 phot$\cdot$cm$^{-2}\cdot$sec^{-1}. /52

Their sensitivity to charged particles creating a background complicates observations by proportional counters. By using special methods, whereby one can select pulses according to shape (rejecting pulses corresponding to particles, and allowing only

for corresponding X-ray quanta), and by introducing blocking by using an additional counter, one can reduce the background by 10-30 times. However, at the present time there is another method which is the use of oblique incidence reflecting parabolic mirrors for incidence angles greater than 88-89 degrees. The use of these mirrors, combined with small counters, will give great advantages when observing weak sources in the soft X-ray region, where $\lambda > 10$ Å, and the reflection coefficient is quite large. The first experiments in this direction have already been conducted. It can be assumed that in the next 10 years the size of counters will be increased to 100,000 cm^2 (3×3 m^2) and this will give a sharp increase to the number of recorded X-ray sources, mainly, extragalactic. Probably, a counter with an area of 100,000 cm^2 will be able to record about 1,000 sources, mainly, extragalactic.

However, the angular resolving power of such a giant counter, as before, will be about one degree. In principle, a substantial increase in the angular resolving power can be obtained by a counter set up on the moon's surface and oriented to the local horizon. Then one can calculate its angular dimension and one of its coordinates according to the rising and setting time of the observed objects over the horizon. In actual fact, the resolving power reaches one angular minute when the counter is moved 3 km farther from the horizon, and the vertical dimension by 1 m.

The second possibility for the substantial improvement of the resolving power in the infrared region of the spectrum consists of

using large, oblique incidence reflecting telescopes with a diameter of approximately 1 m or more. Today, two-mirror oblique incidence systems with a diameter of approximately 10 cm and a resolving power of 5" are being used for photographing the solar disc. It seems compeletely feasible to build a X-ray space telescope weighing several tons with an effective area of several thousand square centimeters, giving a resolving power of 5". The dimensions of such an instrument will be approximately 10 m (Fig. 7). It can be assumed that in this case it will be possible to use a Bragg crystal spectrometer which will increase the spectral resolving power by several orders.

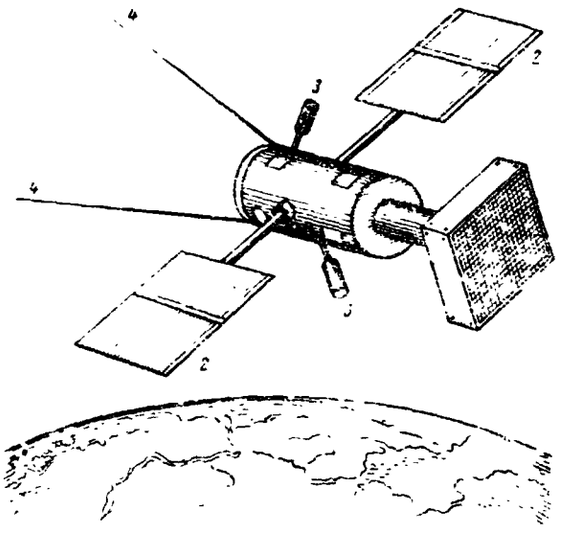

Fig. 7. An imaginary diagram of an X-ray orbital telescope. 1 - Proportional counter with a surface of up to 10 m^2, equipped with a cellular collimator; 2 - Solar batteries; 3 - Orientation telescopes; 4 - Antennas.

The use of spark chambers with an area of sensitivity of 1 m^2 (or above) and weighing more than a ton could be used in the harder region of the spectrum. Such an instrument would detect λ-radiation from extragalactic sources.

A normal optical telescope, with a diameter of 1.5 - 3 m, can be used for the long-distance infrared and submillimeter region of the spectrum. However, requirements for the surface processing of a mirror for

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this region of the spectrum are often considerably lower than for the ultraviolet or optical bands. Of course, an image dimension /53
of 0".1 cannot be achieved in these conditions. This lack of requirements considerably decreases the cost of the mirror itself, the monitoring systems for the quality of the mirror and, finally, orientation and stabilization systems. On the other hand, one can increase the diameter of the mirror and this can prove very useful. Possibly, in this way astronomers will be able to produce a special infrared telescope with a mirror diameter of up to 10 m. Obviously, the weight of such a telescope will exceed 10 tons, although the mirror will weigh little in comparison with those of earth telescopes.

Extraterrestrial Radio Astronomy

Space antennas with measurements from several hundreds of meters to several thousands of kilometers are required in the radio astronomical region of the spectrum, especially for the long-wave area. Several designs of such systems have already been published. Ground observations are made more difficult not only by the ionosphere. In principle, the earth's dimensions themselves do not allow one to increase the resolving power of radio telescopes indefinitely. The defraction limit, equal to λ/D, limits the resolving power for λ = 3 cm by a value of $5 \cdot 10^{-4}$ sec of arc when spacing interferometer antennas at a distance equal to the earth's diameter.

It now seems possible, by taking one of the interferometer antennas into space, to considerably increase the resolving power

of a radio interferometer (Fig. 8). Of course, there are great difficulties for producing such an instrument: there must be simultaneous accurate orientation of both antennas; signal recording must be synchronized with an accuracy of up to 10^{-15} when the antennas are at a distance of L ~ 300,000 km; the signal must be recorded or transmitted to earth on a very wide frequency band. Only in this way can one attain a resolving power of up to $2 \cdot 10^{-5}$ angular seconds.

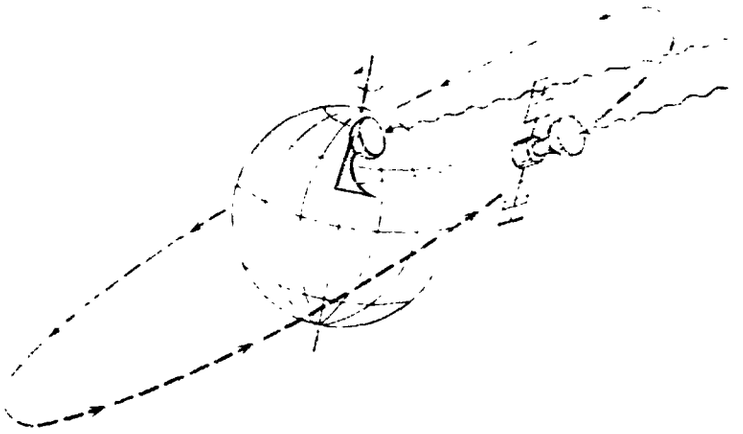

Fig. 8. A diagram of a space radio interferometer; one antenna -- on earth, the other -- in near-earth orbit.

Possibly, the future of extra-atmospheric astronomy will entail the use of large instruments weighing many tons. Each telescope of this type is a unique instrument with practically unlimited /54 use (several years) according to the inexhaustible scientific program. Its great cost, including many years of preparatory work, means that the scientific observation program must be developed thoroughly. Obviously, the use of such instruments can be an

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arena for international scientific cooperation. Bearing in mind that the life span of a large unique telescope is several years, and probably decades, there are three methods for operating such an observatory: fully automated; manned with a changeover crew; and finally, visited by a crew for repairing the systems, replacing equipment, etc. Apparently, all three methods will be used.

It must be noted that for large optical telescopes ultra-precise orientation (0".1 or even 0".01) cannot be achieved in a manned vehicle: the blood circulation in the astronaut's body, heart beats and breathing, and any movement will disturb the stabilization of the telescope if it is rigidly attached to the manned vehicle. This can easily be avoided by using X-ray, gamma-, infrared and radio telescopes, where one can be limited by less accuracy of orientation (see Table).

Region of the Spectrum	λ-radiation	X-ray	Ultraviolet and optical	Infrared	Submillimeter
Required orientation accuracy and resolving power	Approximately 1°	10'	0".1	1"	10"

Greater orientation accuracy is hardly required for astronomical observations. Such accuracy can be achieved if required. The fact is that superconducting gyroscopes, with a deviation of less than 0".001 per year, are being developed for experiments checking the theory of relativity. Possibly, such devices will be the basis

of new stabilization and orientation systems not linked with stars: the position of gyroscope axes can be linked to any system of astronomical coordinates. Although these are forecasts, experience shows that the actual development of equipment always outstrips /55 forecasts, and the further we look into the future, the faster technology develops.

Undoubtedly, during the last 20 years astrophysics has become the most important of the physical and mathematical sciences. One only needs to list the basic discoveries made in that time: the detection of relic short-wave radio radiation, which has confirmed the truth of the hot universe model; quasars, which showed us the metagalactic region, and are close to the boundaries of the universe; pulsars, which are fast spinning neutron stars, theoretically forecast 30 years ago; discrete sources of X-ray radiation; sources of maser radiation of hydroxyl and water vapor, the recording of approximately 20 lines of interstellar molecules, and much more. Almost all these discoveries were made unexpectedly, due to using new technology or discovering new spectral bands. It can be assumed that large orbital telescopes will mean further successes in astrophysics, and today there are more unsolved problems than solved ones. One can only hope that in the next decade the discoveries made will be no less important than those made in this one.

A TASS Report on the Prognoz Flight

"Pravda", April 15, 1972.

A Prognoz automatic station was launched on April 14, 1972 at 3 hours 54 minutes Moscow time in the Soviet Union, in accordance with the outer-space research program.

The station is designed for studying solar activity, and its effect on the interplanetary medium and the earth's magnetosphere. The station weighs 845 kg.

It was put into highly elliptical earth satellite orbit and has the following parameters:

-- maximum distance from the earth's surface (in the apogee) -- 200,000 km;

-- minimum distance from the earth's surface (in the perigee) -- 950 km;

-- orbital period around the earth -- 97 hours;

-- orbital inclination -- 65 degrees.

The station was sent into a predicted trajectory from the intermediate orbit of an artificial earth satellite.

The Prognoz automatic station contains scientific equipment designed for investigating corpuscular, gamma- and X-ray solar radiation, solar plasma fluxes and their interaction with the earth's magnetosphere, and also for further study of magnetic fields in near-earth outer space.

Besides scientific equipment, the station is equipped with: a radio transmitter working on a frequency of 928.4 megahertz, a

radio system for accurate measurement of orbital elements, and a radio telemetry system for transmitting back to earth operational data of instruments and scientific equipment.

According to telemetering information, all on-board systems and scientific equipment are working normally. A coordinating computation center is processing the incoming information.

A Solar Patrol

(TASS)

"Izvestiya", May 19, 1972.

The Soviet Prognoz Observatory in Orbit

The Soviet space research program is wide and varied. The /56
flight of artificial Mars satellites continues, and a Venera-8 Soviet automatic station is approaching Venus. The Luna-19 automatic station has been carrying out scientific research of the moon and near-moon outer space for more than eight months.

The launch of the Prognoz satellite was an important phase in research of the Sun and its effect on the earth.

The links between the Sun and the earth are extremely varied. Everyone knows that solar heat and light give life to the earth. However, apart from radiation in the optical band, the Sun emits radio waves, ultraviolet and X-ray radiation and charged particles. Constantly emitted solar plasma fluxes -- solar wind -- move in interplanetary space at a speed of hundreds of kilometers per second. They flow around the earth and form a void which includes

a geomagnetic field -- the magnetosphere. This area is filled with charged particles of different energy, and magnetic storms occur here. Particles penetrate the earth's atmosphere causing polar auroras and other geophysical phenomena. These processes are due to solar activity.

Spacecraft flights have shown that when there is a solar flare a great number of charged particles of different energy are emitted into surrounding space. Sometimes, their energy is so great that they penetrate the skin of a spacecraft freely, effect the serviceability of the equipment, and can be a danger for astronauts.

Solar observations carried out beyond the earth's magnetosphere tracked the parameter changes of solar wind, the characteristics of solar X-ray and gamma radiation, radio radiation and solar cosmic rays. This information, together with that of ground observatories which carry out constant observations not only of the Sun, but of the earth's magnetic field, cosmic rays, etc., will be used for studying solar activity and this will help to create bases for accurate space weather forecasts. This was the reason for producing the Prognoz automatic station in the Soviet Union.

The station was launched April 14, of this year and was placed into calculated orbit in two stages. At first, the station and the booster unit were placed into artificial earth satellite intermediate orbit.

At the 68th minute of the flight, a programming and timing device switched on the engine of the booster unit which gave

the station additional speed and placed it into calculated orbit.

In accordance with the scientific flight programs, Prognoz station's orbit at a maximum altitude above the earth's surface was 200,000 km, and the minimum 950 km oriented with the apogee toward the Sun.

Trajectory measurement showed that the initial parameters of the station's orbit were close to the calculated ones.

This orbit is unusual since its parameters, especially the minimum altitude above the earth's surface, change significantly /57 due to solar and lunar fields of gravity. These changes in altitude can reach 400 km and above during each revolution.

The Prognoz automatic station (Fig. 9) is a cylindrically-shaped, pressurized container with both ends covered by spherical plates. There are platforms inside the container for attaching equipment. These platforms hold scientific instruments and radio telemetry equipment, solar orientation systems units, and thermal conditions and energy supply units. The pressurized container is filled with inert gas.

The outside surface of the cylindrical section of the container contains several sensors and scientific equipment units, solar orientation system actuator devices, nitrogen bottles and four solar-battery panels. To these panels are fixed a magnetometer boom and a loop antenna for receiving radio radiation of magnetospheric and interplanetary plasma. Scientific equipment

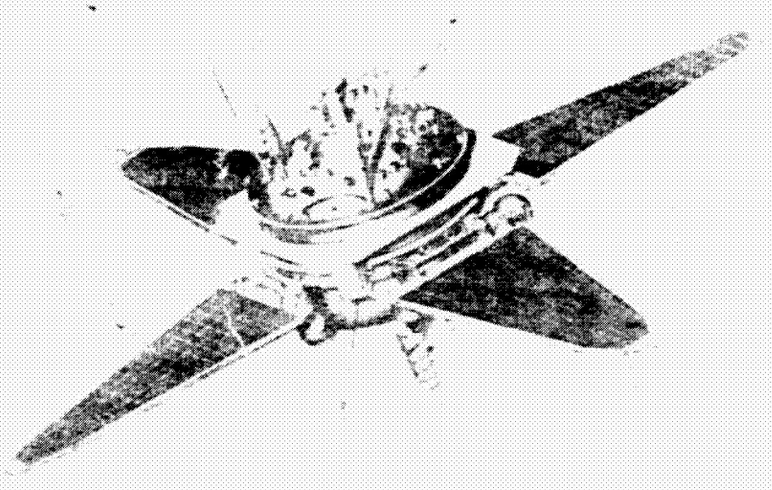

Fig. 9. The Soviet Prognoz automatic station.
1 - Receiving antenna for electromagnetic field low-frequency radiation; 2 - Radio complex semi-directional antenna; 3- Solar orientation center; 4 - Platform with scientific equipment sensors; 5 - Receiving antenna for long-wave radio radiation; 6 - Radio complex semi-directional antenna; 7 - Instrument container; 8 - Solar-battery panel; 9 - Magnetometer boom.

and solar orientation system sensors, radio complex antennas and also telemetry and scientific equipment are attached outside on the end plates.

The whole container surface, and instruments attached to it, is covered by shield-vacuum heat insulation. Sensitive sensor units and the side surface of the container, which is a radiator for the temperature control system, remain open.

The weight of the Prognoz station, when detached from its booster unit, is 845 kg.

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Control of the on-board systems, measurement of movement parameters and scientific and telemetric information from the station, is done by an on-board telemeter complex combined with ground equipment. /56

During the whole flight time, scientific information and data on the operation of various on-baord systems are recorded on a special memory included in the radio telemeter complex. Later, this information is transmitted back to earth.

The station's longitudinal axis must be directed towards the Sun for the scientific equipment and solar batteries to work normally. A solar orientation system brings the satellite into this position, and the station is gyroscopically stabilized in space by twisting.

The station is equipped with passive and active temperature control devices to maintain the required thermal conditions in the instrument container and the required temperature for the individual units of the satellite.

A solar battery is used as an electrical energy generator and a chemical source of current is used as a buffer battery. This energy supply system provides electricity for all the on-board station systems.

Scientific instruments in the satellite are combined into individual groups, depending on the nature of the phenomena investigated. The first group includes instruments for measuring solar electromagnetic radiation emitted simultaneously with solar flares.

These instruments include an X-ray spectrometer with a proportional counter for registering X-ray solar radiation in the energy range 1.5-30,000 electron volts, and a gamma ray scintillation spectrometer in the energy range 30-350,000 electron volts. The instruments with the satellite are continuously oriented towards the Sun.

The second group of instruments is designed for measuring cosmic ray solar fluxes and high energy particles outside and inside of the earth's magnetosphere. This group contains: a spectrometer with semi-conductor detectors for measuring proton fluxes in the energy range 1-35 million electron volts, α-particles and heavy nuclei in several energy ranges; a Cherenkov counter for measuring electron fluxes in energy ranges 40-140,000 electron volts, and a scintillation spectrometer for measuring proton fluxes with an energy of 30-210,000 electron volts.

The third group contains instruments for registering plasma characteristics of solar wind beyond the earth's magnetosphere, in the transition region between the shock wave front and the boundary of the magnetosphere, and also inside the magnetosphere.

The fourth group of instruments includes radio radiation receivers in the 1.6-8 kilohertz and 100-700 kilohertz range, a magnetometer, instruments for determining the satellite's complete spatial orientation, and also equipment for measuring the penetrating radiation dose on the flight track.

Information obtained from the Prognoz satellite for the period from April 14 this year, shows the relatively calm condition of an interplanetary medium, characteristic of the beginning of a

minimum of solar activity. The average speed of solar wind was 300 km per sec, and the intensity of the magnetic field was 6-8 gamma. The flux dimension of its primary cosmic radiation was 4.8 particles per cm^2 per sec. X-ray solar radiation did not exceed the background value. During April 20 1972, effects were observed linked with a solar flare, after which charged particle fluxes were generated.

While the satellite was in operation, information was /59
obtained on the shape of the magnetosphere in the high latitude region, and also on the characteristics of the transition region between the boundary of the magnetosphere and the interplanetary medium.

Data from satellite and ground observations were compared and analyzed. Information arriving from Prognoz continues to be processed. The results of the experiments will be published in the scientific press.

Two Prognoz Automatic Stations in Joint Flight

(TASS)

"Pravda", June 30, 1972.

The Prognoz-2 automatic station was launched in the Soviet Union on June 29, 1972 at 6 hours 47 minutes, Moscow time, to widen the research into solar activity processes and their effects on the interplanetary medium and earth's magnetosphere, which were begun by the Prognoz stations.

The joint scientific experiment which will be conducted during the flight of the two Prognoz automatic stations, put into near-earth highly elliptical orbits, is a component part of the outer space research program being carried out in the USSR. The Prognoz-2 station was put into earth satellite orbit with the following parameters:

-- maximum distance from the earth's surface (in the apogee) -- 200,000 km;

-- minimum distance from the earth's surface (in the perigee) -- 550 km;

-- orbital period -- 97 hours;

-- orbital inclination -- 65 degrees.

Putting the Prognoz-2 station into the predicted trajectory was done exactly as when launching the Prognoz station, from an intermediate artificial earth satellite orbit. Scientific equipment in the Prognoz-2 station is designed for researching into corpuscular, gamma- and X-ray solar radiation, solar plasma fluxes and their interaction with the earth's magnetosphere, and also for further study of magnetic fields in near-earth outer space.

The station is also equipped with French equipment for conducting experiments into the study of solar wind characteristics, the outer regions of the magnetosphere, gamma solar radiation and search for neutrons of solar origin, in accordance with a Soviet-French program of cooperation in the exploitation and research of outer space.

The Prognoz automatic station, launched on April 14, 1972, continues scientific research in accordance with the flight program and on June 29 had completed 20 revolutions around the earth.

According to telemetering information, the on-board systems and scientific equipment of both stations are working normally. The long-range space communications center is controlling the joint flight of the two stations. Information arriving from the Prognoz and Prognoz-2 is being processed at the coordinating computation center.

A Prognoz Relay Race

"Krasnaya Zvezda", July 1, 1972.

The second automatic station Prognoz-2 (first launched on April 14) has begun a scientific watch in space. Now, two space observatories are simultaneously researching into solar activity and its effect on the interplanetary medium and terrestrial processes according to a single program. The new station is equipped with additional instruments produced by French scientists. /60

The scientific director of the experiment, I. A. Savenko, in a conversation with the TASS correspondent talked about the value of the Prognoz satellites in researching into the deep and many-sided links between processes on the Sun and on earth.

"First of all, I would like to draw attention to the unusually elongated orbits of both flying observatories. The automatic stations, as it were, are "advanced" to meet the Sun. This trajectory

is necessary when one is investigating solar corpuscular radiations and their effects on geophysical processes. It is now reliably established that the Sun, in a calm condition, constantly emits into surrounding space plasma fluxes called solar wind. This cosmic "trade-wind" blows evenly and continually in interspace.

It was found that its average speed in interspace is approximately 300 km/sec.

Prognoz and Prognoz-2 are obtaining interesting information, the analysis of which will allow us to establish the effect of solar matter and corpuscular radiations on the radiation belts of the planet, and help us to understand the nature of magnetic storms, polar auroras and other geophysical phenomena.

One very important task is done by these space stations during solar flares, when the influence of the Sun on our planet is felt considerably. It is known that during flare periods intense plasma fluxes flow from active solar regions and move at a speed of approximately 1,000 km/sec. This powerful space "hurricane" with its own magnetic field, bursts through the quietly flowing solar wind.

Of course, research into the interaction of solar plasma on the earth's magnetosphere is by no means the only task of Soviet flying observatories. They are equipped with instruments which can observe the Sun and record the wide range of its radiations: from X-ray and gamma rays to very long radio waves. Electromagnetic radiations, traveling with the speed of light, are the first "heralds" of flares and other active processes taking place on the

surface and inside the Sun. Apart from this, both automatic stations are equipped with instruments designed for recording different charged particles -- electrons, protons and heavy nuclei of cosmic rays of solar and galactic origin.

French researchers are very interested in this sphere of space physics. They have produced two original instruments which supplement the Soviet equipment in the second Prognoz. These are intended for investigating plasma and fluxes of solar neutrons beyond the earth's atmosphere.

The close cooperation of physicists, and the joint effort of scientists of different countries in studying the Sun, similar to that in the present experiment with the Prognoz-2, will undoubtedly help to use experience, efforts and scientific means for the benefit of mankind."

LAUNCHES OF SATELLITES IN THE KOSMOS SERIES DURING 1972

No. in sequence	Launch date	Name of vehicle	Orbital period, min	Apogee, km	Perigee km	Orbital inclination to the equatorial plane, degrees	Radio transmitter frequency, megahertz	Notes
1	12January	a «Космос-471»	89,[illegible]	323	202	65		
2	25	«Космос-472»	102,4	1568	207	82		
3	3February	«Космос-473»	89,7	333	209	65	19,995	
4	16	«Космос-474»	89,8	347	207	65		
5	25	«Космос-475»	105,0	1013	977	71		
6	1March	«Космос-476»	97,2	651	618	[illegible],2		
7	4	«Космос-477»	89,6	328	212	7[illegible],9	19,995	
8	15	«Космос-478»	89,5	319	213	65,4		

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No. in sequence	Launch date	Name of vehicle	Orbital peri period, min	Apogee, km	Perigee, km	Orbital inclination to the equatorial plane, degrees	Radio transmitter frequency, megahertz	Notes
9	22 March	«Космос-479»	95,2	549	517	74		
10	25	«Космос-480»	109,2	1212	1183	83		
11	25	«Космос-481»	92,4	540	279	71		
12	31	«Космос-482»	201,4	9813	210	52		
13	3 April	«Космос-483»	89,8	345	212	72,9		
14	6	«Космос-484»	88,8	236	203	81,3	19,995	
15	11	«Космос-485»	92,1	506	280	71		
16	14	«Космос-486»	89,1	267	214	81,4		
17	21	«Космос-487»	92,3	531	278	71		
18	5 May	«Космос-488»	89,5	319	211	65,4		
19	6	«Космос-489»	105,0	1010	980	74		
20	17	«Космос-490»	89,4	310	212	65,4	19,995	
21	25	«Космос-491»	89,5	303	210	65		
22	9 June	«Космос-492»	89,8	342	209	65		
23	21	«Космос-493»	89,5	308	213	65	19,995	
24	23	«Космос-494»	100,8	829	791	74		
25	23	«Космос-495»	89,3	298	206	65,4		
26	26	«Космос-496»	89,6	342	195	51,6	20,008	
27	30	«Космос-497»	95,2	812	282	71		
28	5 July	«Космос-498»	92,1	511	282	71		
29	6	«Космос-499»	89,2	283	209	51,8		
30	10	«Космос-500»	95,2	554	509	74		
31	12	«Космос-501»	108,8	2149	222	48,5		
32	13	«Космос-502»	89,2	284	206	65,4		
33	19	«Космос-503»	89,4	304	208	65,4		
34	20	«Космос-504»	115,2	1540	1425	74		Eight satellites put into orbit by one launch vehicle
35		«Космос-505»						
36		«Космос-506»						
37		«Космос-507»						
38		«Космос-508»						
39		«Космос-509»						
40		«Космос-510»						
41		«Космос-511»						
42	28	«Космос-512»	89,3	291	207	65,4	19,995	
43	2 August	«Космос-513»	89,8	340	204	65		
44	16	«Космос-514»	104,4	999	953	83		
45	18	«Космос-515»	89,3	309	205	72,9		
46	21 Augus.	«Космос-516»	89,6	277	256	65		
47	30	«Космос-517»	89,4	305	207	65	19,995	
48	15 September	«Космос-518»	89,6	330	208	72,9	19,995	

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No. in sequence	Launch date	Name of vehicle	Orbital period, min	Apogee, km	Perigee, km	Orbital inclination to the equatorial plane, degrees	Radio transmitter frequency, megahertz	Notes
49	16	«Космос-519»	89,8	343	210	71,3		
50	19	«Космос-520»	710,6	39319	652	62,3		
51	20	«Космос-521»	105,0	1030	973	65,8		
52	4 October	«Космос-522»	89,8	342	214	72,9		
53	5	«Космос-523»	92,0	507	283	71		
54	11	«Космос-524»	92,3	537	277	71		
55	18	«Космос-525»	89,3	292	208	65,4	19,995	
56	25	«Космос-526»	92,0	511	282	71		
57	31	«Космос-527»	89,7	330	214	65,4		
58	1 November	«Космос-528»	114,0	1495	1375	74		Eight satellites put into orbit by one launch vehicle
59		«Космос-529»						
60		«Космос-530»						
61		«Космос-531»						
62		«Космос-532»						
63		«Космос-533»						
64		«Космос-534»						
65		«Космос-535»						
66	3	«Космос-536»	95,2	555	514	74		
67	25	«Космос-537»	89,6	324	207	65	19,995	
68	14 December	«Космос-538»	89,4	305	212	65,4		
69	21	«Космос-539»	113,0	1392	1353	74		
70	26	«Космос-540»	100,8	823	770	74		
71	27	«Космос-541»	90,3	371	242	81,4		
72	28	«Космос-542»	96,4	653	554	81,2		

Key throughout table: a. Kosmos

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II. SATELLITES IN THE NATIONAL ECONOMY

Meteor Satellites Keep Watch

Professor I. Andronov

"Pravda", May 25,1972.

The Meteor meteorological space system has been in constant /63
operation for five years. During this time much material has been obtained for studying the uniformity of global meteorological formations, developing new methods for transmitting information on atmospheric conditions, and widening the use of space vehicles used in this system in the interest of the national economy.

For example, Meteor satellites have recorded thousands of cyclones and given the position of tens of thousands of atmospheric fronts. Meteorological satellites have been used for selecting the best routes for vessels in ocean waterways. As a result, it was possible, on an average, to reduce the steaming time by 5-7%, and this produced great economy

Meteorological satellites show the ice conditions and ice cover in the Arctic and Antarctic in polar day and night conditions. This has considerably increased the navigation period along the North Sea route. Cloud information, transmitted by satellite, is important for civil air transport, especially flights along intercontinental routes.

As a result of long-term use of the meteorological system, features, unknown earlier, were established for determining the cloud cover and development of atmospheric processes. Hence, before meteorological satellites there were many unexplained questions on the occurence and evolution of tropical cyclones, their origins and movement. Similar information has been useful when vessels leave the Soviet Union for areas of the world's oceans where cyclones and typhoons systematically occur. Atmospheric processes, for example, in the Southern Hemisphere, must be closely studied to ensure the safety and economy of these trips.

Analysis of material obtained from the Meteor satellites has enabled workers at the Hydrometeorological Center of the USSR to establish three points where cyclones occur in the Indian Ocean. They are all close to Java.

Information from artificial earth satellites has given new concepts of the atmosphere and properties of our planet. For example, it was found that the atmosphere extends not in the order of a hundred kilometers, as was believed earlier, but several thousands of kilometers from the earth's surface.

The problem has also been successfully solved for processing hundreds of thousands of photographs simultaneously transmitted from several satellites. For this, a ground reception complex has /64 been established for processing and distributing information, and reception information points have been set up in various parts of the country.

The foundations have been laid for transferring to basically new numerical methods of weather forecasting. They are gradually being introduced and used in practice. The development of these methods needs new requirements of information obtained from the meteorological satellite system. The direct transmission of satellite information, accurate maps for the distribution of temperature over the earth's surface, and information on temperature distribution over the whole layer of the atmosphere are now very important. The Meteor satellite, launched on April 17, 1971, tested spectrometric equipment for determining the vertical temperature profile in the atmosphere. The Meteor satellite which went into orbit on December 29, 1971 is testing improved television equipment built by a Soviet scientist and engineers which transmits directly; ground stations, equipped with simple receiving equipment and a small antenna, receive the pictures. Five to ten minutes after a satellite has flown over, a picture of the cloud cover and the underlying surface area of several millions of square kilometers is received at the station.

Meteorologists must now have meteorological information from practically all areas of the earth. It must coincide with synoptic periods -- to moments when meteorological measurement is being done simultaneously throughout the whole world. It is also important that this information is uniform and the scale of television pictures is identical. These requirements can be satisfied when the orbit parameters are stabilized by vernier engines in the satellite. By taking into account that satellite operating time is

calculated in years, the vernier engine installations must have a sufficient reserve of propulsive mass and withstand repeated cut-in.

Soviet scientists have developed ion-plasma electrojet rockets for reducing the reserve of propulsive mass for such satellites. They use solar energy and create gravity through plasma scattered in electromagnetic fields. Stationary electrojet engines were tested for the first time in space in the Meteor satellite launched on December 29, 1971.

The Meteor space system is constantly developing. In the near future these satellites will transmit complex meteorological data on the whole world twice a day. In the future, the meteorological system will include space vehicles situated in three layers.

The first layer will include long-term manned orbital stations. These will provide visual observations of the geosphere and high-speed meteorological phenomena, high tides, landslides, dust and sand storms, tsunami, hurricanes and earthquakes. The second layer -- automatic satellites of the Meteor type in polar or circumpolar orbit at an altitude of 1,000-1,500 km. Their main task is to provide information required for numerical methods of weather forecasting on global and local scales, and conduct observations on medium-scale and small-scale processes in the atmosphere. Finally, the third layer consists of meteorological satellites orbiting at altitudes of up to 36,000 km for continuous observation of dynamic processes in the earth's atmosphere. They will give a picture of the overall atmospheric circulation.

By adding the information from space vehicles on all three layers, scientists will be able to forecast accurately the course of events in the atmosphere and this will help us attain the cherished goal -- control of the weather.

Satellites providing information are not only valuable for meteorologists. Television and infrared pictures from space will /65 help us study the earth on a continental scale and over the planet as a whole. As a result, new scientific directions have appeared -- space geography, space geology, and space geodesy. Complex study of the earth by interpretation of space pictures has appeared.

Geologists were the first to use television pictures and this is quite understandable. They have used aerial photography for research for a considerable time. However, the maximum area of the earth's surface which can be covered from an aircraft in one picture is 1,000-1,200 square kilometers. Whereas the length of geological structures -- folded systems, depressions, and geofractures is measured in hundreds and even thousands of kilometers. Large geological formations such as these can only be seen in their entirety from space altitudes. It appeared that television pictures from Meteor satellites had "X-ray" features -- small details of the landscape, forests, and alluvial rocks did not hide the earth's geological structure.

By using television information, scientists at the All-Union Aerogeological Trust built up a telephotometric diagram of a large territory with an area of approximately six million square kilometers. Geological interpretation of it not only confirmed new

results of ground and aircraft geological research, but changed the concept of the tectonic formation of the area and new concepts of its geological structure were formed. In particular, the photographs showed fractures not detected by ground geological expeditions. These fractures are often indicative of minerals or areas of increased seismicity.

The meteorological system of the future will open up new prospects for researching the earth's natural resources. Information on the vertical temperature profile in the atmosphere and the earth's surface is necessary for different branches of agriculture. Probing of the air envelope gives information on moisture reserves, and television pictures in different spectral bands, including color, will give information on crop capacity, crop germination, forest and land reserves and fires. Information on the boundaries and solidarity of ice fields, the sea state and temperature will be very valuable for the fishing industry. This information will arrive systematically, operatively, and in large quantities. Therefore, in my opinion, specialized organizations must be set up in different branches of the national economy to solve problems for the complex processing of information transmitted from Meteor satellites.

The directives of the 24th Congress of the Communist Party of the Soviet Union envisaged the use of space technology in the interests of the national economy. The Meteor space system is being used for this purpose. Three satellites, launched into near-earth orbit in 1971 and 1972, are continuously supplying

meteorologists with complex information. In three more Meteor satellites, launched in 1969, 1970 and 1971, research is being conducted into the long-term operation of on-board equipment in outer space. The results of these experiments will help further research in long-term meteorological space observatories.

The "Vertical" Searches for the Earth

B. Gerasimov

"Sotsialisticheskaya industriya", January 30, 1972.

A Report from the Space Assembly Site

I entered this amazing world of space technology with anxiety. /66 Of course! A fascinating journey awaited me through laboratories and workshops where the famous Meteor satellites are born.

The "miracles" began in the first laboratory. In a room with tightly curtained windows I was led to a small infrared set. Intricate lines were frantically drawn on a screen with an attached oscillograph.

"This is the result of your entrance," one of the engineers explained. "The instruments reacted to additional heat which you brought into the room."

A few turns of a handle and the equipment "adapts itself" to my presence. An electronic beam again draws an almost straight line.

"You may smoke ..."

I go into a far corner and strike a match. The oscillographs again react wildly. When the cigarette was extinguished, the lines on the screen did not calm down for some time, registering the cooling of the cigarette I had thrown away.

"Infrared instruments are very sensitive. This is why we use them as sensors orienting a satellite relative to the earth.

Of course, one can use other types of sensors, for example, optical or radar. Infrared instruments were used widely during tests in the first satellites.

This is how they work. Infrared sensors in a satellite "sense" only two hot bodies: the earth and the Sun. The radiation of planets and distant stars is not taken into account. But in this situation there is a complication in that the Sun as a source of energy has no competitor. If one does not take precautions, infrared sensors can "forget" the earth and begin to orientate toward the Sun.

This can be avoided by using special limitors. The Sun, as it were, blinds them and forces infrared sensors to immediately turn and search for a warmer body -- our planet. This unusual receiver is always built for ground waves in the range from 7-40 μm. Special automatic equipment enables it to find the required wave and aim towards the earth.

My visit to the laboratory coincided with the testing of a "vertical" earth search system. The "eye" of the instrument is a thermal-sensitive element constantly facing the earth. It is very

sensitive and it must even be protected from light. It is not so simple to find such a material for the screen, but after persistent search it was found.

The sensor is not the solution to the problem. Where can one find an "Archimedes point of support", to apply force capable of turning the satellite into the required direction? Previously, this was done by a microjet which created the required twisting moment. Of course, such "small engines" could not work for very long. One had to put too much fuel into the satellite and this reduced the amount of useful instruments."

I was shown several unique electromotors with huge rotors. They are switched on at the required moment of time and begin to rotate in any direction. The satellite itself, according to the law of action and reaction, turns to meet it. The motors are fed from solar batteries. The "fuel distance" is months and years.

Incidentally, the "vertical" solves another problem. Solar sensors mounted with it are directed towards the Sun and turn the /67 wings of the solar batteries towards it.

After the "Vertical" I am shown other assemblies of the Meteor satellite. For example, space bearings on which the wings of the solar batteries rotate. Ordinary bearings need lubrication and, as a rule, in normal conditions, work well. But in space? Lubrication immediately boils away in a high vacuum, and moving parts will weld tightly together and will certainly not rotate. Designers have successfully dealt with this problem. Many assemblies and units of the Meteor are original technical solutions.

Supersensitive meteorological instruments, delicate television equipment, computing "boxes", filled with miniature electronics, and compact memories ... Research organizations have devoted much effort for space technology to become a miraculous reality.

The Meteor main assembly shop is especially interesting. After numerous tests all the satellite's units and assemblies arrive here. These tests are complex and as close as possible to actual space conditions. Some components are "tempered" in a radioactive radiation furnace, others "become accustomed" to high vacuum in a low-pressure chamber, and others are tested for overloads. Only components which survive this "purgatory" are suitable for assembly. Now for the body of the satellite, composed of complex equipment. The assembly of space vehicles is, indeed, a unique one. There is no room for errors, and in long flights there are still no experts capable of correcting any possible defect.

The satellite's wings, its solar panels, are fixed separately. They are attached just before the launch and look like the compressed bellows of a huge accordian beneath the protective cover of the launch vehicle. The solar wings only open to their full extent in orbit, as do the "umbrellas" of the satellite's transceiving antennas.

While final tests are being done, workers are carefully packing /68 the new satellite. The acceptance department gives its approval and the satellite can continue its journey to the space launch area (Fig. 10).

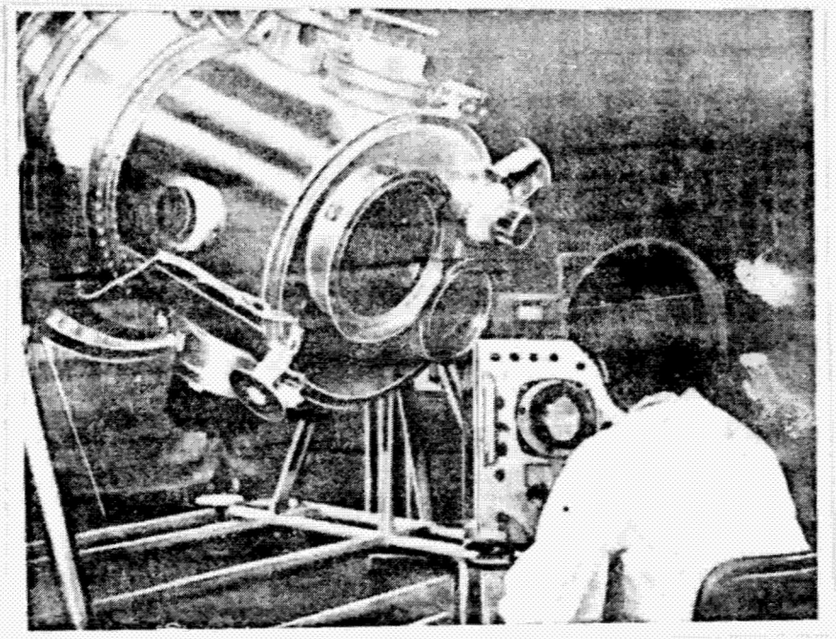

Fig. 10. The Meteor is assembled. Final testing.

A safe journey to you Meteor, our space envoy!

The Next Communication Session

B. Gerasimov

"Sotsialisticheskaya industriya", January 30, 1972.

Telegrams from the coordinating computation center are always laconic. The accurate orbit parameters of the next Meteor revolution and the time for beginning the communication session, this is all the information which arrives at the meteorological satellite information reception point.

We shall visit one of these points. It is a small two-story house, a square covered with melting snow in the center of which

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a huge metal plate is suspended on a circular column (Fig. 11). The plate, or more accurately, the several hundreds of protruding caps of it, is the receiving antenna. The caps are made of special plastic and so-called emittors protect them from bad weather and differential pressure. Each one of them collects information from space; a "radio whisper" of all the emittors join into a "united choir". But this is still too weak and must be amplified by electronic equipment.

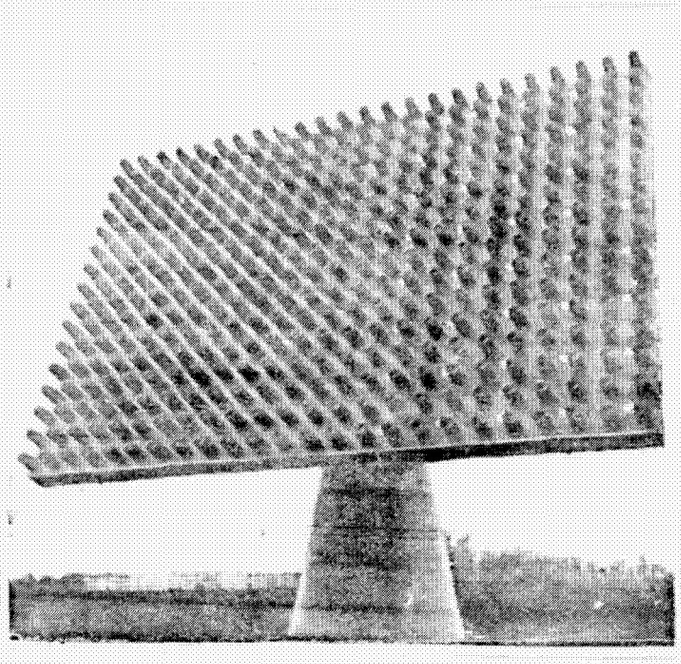

Fig. 11. An antenna for receiving signals from Meteor satellites.

A 15-minute readiness is announced. In 15 min the Meteor will enter the radio visibility zone. The equipment is checked for the last time and the frequency is adjusted to the signal level. The Meteor appears. Of course, it is not seen visually, but sensitive radio electronics has already detected the satellite and the antenna plate is tracking it. At an order from the flight control center the Meteor is switched to transmit. The satellite "reports" all the information and data accumulated during its last revolution. It has observed millions of square kilometers of the earth's surface.

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Now photographs are transmitted from orbit to earth. I recog- /69
nize on television screens well-known features of the earth's continents, seas and oceans. Here is a night photograph of the Caspian. In fact, it is a thermal portrait made in infrared rays. At night, water is warmer than the surrounding shores and, consequently, produces a stronger (brighter) signal. The coastal strip is darker. At daytime there is a different picture.

Photographs, hundreds of photographs. Part of the planet is covered by cloud, but one can see the "eye" of a future typhoon. It is amazing to see the whole planet and its contrasts at one time. Almost all the Northern Hemisphere is already covered in snow, and in the Southern Hemisphere it is summer.

But not only photographs "determine" the weather. The satellite transmits information on the temperature and heat reflected and radiated by the earth.

Of course, information from space is supplemented with that from the ground. The world's weather survice, hundreds of meteorological stations where thousands of observations are made daily: wind speeds are measured and the temperature of air masses is recorded... Here there are no fine details, one must take into account each parameter and transmit it to the hydrometeorological center in good time. All information from these reception points is transmitted to Moscow -- the country's hydrometeorological center which has links with capitals of the whole world. Today, many countries are exchanging meteorological information.

A wealth of information arriving in Moscow is fed into high-speed computers and several minutes later becomes a weather forecast for tomorrow and subsequent days.

Space Meteorologists

V. Yakimenko

A scientific reviewer of the "Moskovskiy komsomolets"
"Moskovskiy komsomolets", June 29, 1972.

Everyone is interested in the weather; corn-growers preparing to work in the field, captains of ships making trips of thousands of kilometers, and pilots whose aircraft cover various climatic zones in a single flight. Each day we wish to know what the weather will be.

For a long time man has observed the weather, tried to fix laws for its formation and attempted to forecast it. There are meteorological stations on every continent. The atmosphere is studied by radiosondes and metecrological high-altitude rockets; meteorologists use automatic stratospheric balloons, ships, and laboratories in aircraft. If one looks at a picture of the planet one can see the irregular sitings of meteorological stations. Areas where weather is "born" -- large expanses of sea and ocean which occupy more than 70% of the earth's surface, are not covered by permanent meteorological observations. It is difficult to set up and use meteorological stations in polar regions, mountainous areas, deserts and in the taiga.

Here, meteorologists are helped by automation. Automatic stations have been built and are working successfully to give information on the strength and direction of the wind, air temperature, the amount of rainfall and atmospheric pressure. New meteorological observations on a world scale are required for reliable and long-term weather forecasting. Meteorological satellites have become the technical means for solving this problem.

A modern meteorological satellite is an automated laboratory. Its capabilities are such that in one revolution of the earth it examines more than 8% of its surface, and in a day observes the whole planet. Information collected by a meteorological satellite /70
in one revolution is 100 times greater than that which is collected from all the meteorological stations in the world. At the present time, there are more than 10,000 of these! Let us say immediately, that the requirement for ground observations has not diminished with the appearance of meteorological satellites. At the present time, traditional technical means and meteorological satellites are supplementing each other and form a single meteorological service. For example, one remembers the complex joint research carried out by the crew of the Soyuz-9 spacecraft, the Meteor meteorological satellite and the research ship Akademik Shirshov in June 1970. This work was carried out by different means and methods at different altitudes. Such research supplements each other and improves methods and technical facilities.

The production of meteorological satellites and creation of a permanent meteorological system in the USSR was done in several

stages. During the first stage electrotechnical devices which stabilized a satellite and orientated its body towards the center of the earth were produced and tested in Kosmos-14 and Kosmos-23 satellites.

Six years ago the Kosmos-122, the first Soviet meteorological satellite used for obtaining information, was put into orbit and began its work and was used for weather forecasting. This launch was the beginning of the second stage in producing meteorological satellites, and then a permanent meteorological satellite system. The first important problem was solved when this meteorological satellite was used -- obtaining information on cloud cover on the earth's night side. Many complex technical problems were also solved during the flight. For example, two independent orientation systems were used in the satellite: one for continuous orientation of the instrumentation section towards earth, the other for the orientation of solar batteries towards the Sun. The satellite operated for four months and regularly transmitted extensive meteorological information. Analysis of information received showed that calculations and technical solutions taken when the satellite was being built were correct, as were the methods for meteorological observations.

This work allowed us to move to the third stage. Meteorological satellites Kosmos-144 and Kosmos-156 were launched in 1967. The launch of the second of these was done so that the initial plane of its orbit was shifted by 95° relative to the plane of the orbit of the first. In this way, observations were made over

each area of the earth with an interval of approximately six hours, and the development of atmospheric processes was traced. With the launch of the satellites by the USSR work was begun in April 1967 on the the Meteor experimental meteorological system, including two simultaneously operating satellites and a ground complex of control, reception, processing and distribution of information.

Important experience in satellite meteorology was gained during 1968 through the simultaneous observations by three satellites in the Kosmos series -- 144, 184 and 206. The choice of orbits for these satellites made it possible to solve several interesting problems. The first two satellites were in orbits whose planes were almost perpendicular to each other. In this way, information was obtained over specific geographical areas twice a day at six-hour intervals. This is important for analysis and weather forecasting since one can trace the development of atmospheric processes with time. Observations by the Kosmos-206 were done from practically the same orbit as the Kosmos-144, but approximately 20 minutes later. Although the meteorological situation hardly changed during this time, it was possible to carry out an objective verification of information obtained. If one takes into account that by the time the Kosmos-206 was launched its /71
predecessor Kosmos-144 had been in orbit more than a year, therefore comparison of the characteristics of the on-board equipment of the two satellites was made and the effect of long-term space flight on its serviceability was checked. It must be noted that when

three meteorological satellites are working simultaneously it is more difficult to control them and the system as a whole, and the amount of telemetering information arriving on earth increases.

In March 1969 the first series-produced Meteor meteorological satellite, which was part of the meteorological system created earlier, went into orbit. The operations carried out by Meteor satellites are varied. They obtain an image of the cloud cover over the whole earth using phototelevision equipment. Special equipment fixes thermal radiation fluxes and the planet's thermal balance is calculated according to them. Land and sea temperatures are measured, moisture content in the atmosphere is calculated, the temperature distribution according to altitude in the troposphere and stratosphere is measured, the altitude of the upper cloud boundary is determined and observations are made on the condition of ocean surfaces and the ice cover boundary.

The Meteor system has been operational for more than five years. We will give one example showing the economical effect of using meteorological satellites in the national economy. Obtaining information on weather conditions over the ocean allows one to choose the best routes for vessels and, on an average, saves 5-7% of their steaming time. Information obtained by satellites on the ice cover in the Arctic considerably increases the navigation period through the North Sea route. For example, one remembers that in 1967 the eastern sector of the Arctic was navigable for vessels a whole month earlier mainly due to the Kosmos-144 meteorological satellite. Meteorological satellites study processes

causing the occurrence and evolution of tropical cyclones, areas where they originate and movements. This is extremely important when ships leave the Soviet Union for areas of the world's ocean where cyclones and typhoons occur. The safety and economy of these trips, to a great extent, is provided by the Meteor system. The work of producing and successfully using the Meteor system was awarded our country's highest order -- the Lenin Prize.

Meteorological satellite equipment and systems are constantly being improved. Spectrometric equipment for determining the vertical temperature profile in the atmosphere was tested in the Meteor launched in April 1971. Television equipment, transmitting directly, was tested in the Meteor launched in December 1971. Five to ten minutes after the satellite has flown over, the receiving station obtains a photograph of the cloud cover and the underlying surface area of several million square kilometers. Ion-plasma electrojet engines, using solar energy, were tested in this same satellite. The need to produce such engines, especially for meteorology, is that in order to carry out simultaneous observations on a world scale and obtain uniform information and uniform television pictures orbital parameters must be stabilized. This can be done by using vernier engines. Long-term meteorological satellites have created these requirements of such engines -- multiple cut-in and a sufficient reserve of propulsive mass. Electrojet engines fulfill these requirements.

Meteorology is one of the spheres of man's activity where there is a great need for cooperation between countries. The

Soviet Union is making a valuable contribution to the discovery of nature's secrets, and is actively participating in international /72
cooperation between weather services of different countries. The types of cooperation can be varied. There is a regular exchange of meteorological reports, the Soviet hydrometeorological center is one of three world meteorological centers which obtains weather information from the whole world (the two others are in Washington and Melbourne). Here, processing is done and weather reports are sent from Moscow to all corners of the earth. One of the tasks set by the directives of the 24th Congress of the Communist Party of the Soviet Union for the five-year development plan of the national economy in the USSR for 1971-1975 is the "implementation of research work in space for development ... of meteorological forecasting ... by using satellites, automatic and manned vehicles ...". The Meteor space meteorological system is successfully solving these important national economic problems.

Earth from Space

"Sovetskaya Rossiya", April 19, 1972.

One important national economic problem which is being successfully solved by artificial satellites is the long-distance study of our planet's natural medium from space. K. Ya. Kondrat'yev, a corresponding member of the Academy of Sciences of the USSR, tells the TASS correspondent of successes achieved and prospects in this sphere.

"Scientific and technical progress has become a particularly actual problem in the comprehensive study of the natural medium. A complex problem of this kind is only possible by using satellites. Until now, only the first steps have been made in studying our planet by space technology. However, the possibility for discovering the nature of the earth and the riches beneath it and in the oceans is extremely wide. The complex combination of space and ground methods will give the best results.

The production of models of fish catches in the world's oceans can be an example. Forecasting the migration of shoals is very important for successful fishing, since the environmental conditions affect fishing operations. Here, one most know the position, the extent of the catch areas, the density of fish in the fishing area, the effect of the shoal, the state of the ocean's surface, and other characteristics. One will spend ten times as long searching for fish than catching them without accurate forecasting. Much of the required information can be obtained remotely,and in good time, by using satellites. Other characteristics, for example, the chemical compsition of the water, can only be obtained by direct measurement -- sea buoys. Therefore, the solution lies in the complex use of long-distance and direct measurement methods.

Later, I shall deal with the useful work being done by Meteor satellites continuously carrying out a space weather patrol. They contain equipment which can determine the meteorological situation in various parts of the earth by day and night.

Scientific equipment in Soviet meteorological satellites includes actinometric instruments for measuring solar radiation reflected by earth, and also the amount of heat radiated by the planet into outer space. This allows us to study the laws of planetary distribution of the influx and efflux of heat, in other words, obtain information characterizing the energetics of the earth. Research during recent years has caused substantial corrections to be made to our previous concepts of the energetics of the planet on which we live.

An actual part of the program of long-distance probings from /73
space is the study of the various characteristics of the earth's surface. An interesting experiment was conducted during the formation flight of Soyuz-6, Soyuz-7 and Soyuz-8. Here, photographs were taken from space of the spectra of various natural formations. A synchronous complex of optical measurements taken on earth and in two flying laboratories, at different heights, was carried out. Later, research was continued during the Soyuz-9 flight. Analysis of the results obtained showed that complex data allows one to carry out very minute differentiation of natural formations.

In my opinion, there are many problems which can only be effectively solved when using manned spacecraft, the crews of which are specialists trained for carrying out the appropriate scientific program. The need for continuous and complex observations in long cycles requires long-term manned orbital stations. They can become actual space bases for researching into the earth's natural medium and resources.

One of the decisive advantages of such stations is the fact that a man in them can carry out logical analysis of the situation and take decisions on which objects to research. One can also determine which set of equipment (of that contained in the spacecraft), which will give the fullest information on the phenomena investigated. Naturally, the flight engineer will adjust any faults in the equipment and will guarantee its prolonged and effective use.

The change-over crews of orbital stations can take back to earth experimental materials (for example, photographic film) for analyzing the data and, if necessary, for subsequent correcting of the experiment program.

Interest in using space technology methods for discovering our planet's secrets is increasing each year. Geology and geomorphology, hydrology and oceanology, geobotany and agrobiology, these are just some of the sciences which profit from the use of artificial satellites."

A TASS Report: The Molniya-1 and SIS* in Space

"Pravda", April 6, 1972.

In the Soviet Union on April 4, 1972 the Molniya-1 communications satellite and the SIS small French independent satellite were launched by one launch vehicle. The Molniya-1 and SIS satellites were put into highly elliptical orbit with an apogee of

*Translator's note: SIS is Small Independent Satellite.

39,260 km in the Northern Hemisphere and a perigee of 480 km in the Southern Hemisphere.

The satellites' orbital period is 11 hours 45 minutes, the orbital inclination is 65.6°.

The Molniya-1 communications satellite is designed for using the long-range telephonic and telegraphic radio communications system, and also for transmitting Soviet Central Television programs to points in the Orbita network in the extreme north, Siberia, the Far East and Central Asia.

Apart from equipment for transmitting television programs and providing long-range multi-channel radio communications, the satellite has command and measurement equipment, and also systems which orientate it, correct its orbit and supply energy to it.

According to information, the equipment in the satellite is working normally.

Communication sessions via the Molniya-1 will be carried out /74
according to a certain program.

The SIS French satellite is designed for investigating the characteristics of different solar batteries in outer space.

The SIS satellite was launched in accordance with a program of cooperation between the USSR and France in the research and use of outer space for friendly purposes.

Ground stations in France are tracking the SIS satellite's flight and are receiving information from it.

A TASS Report on the Molniya-2

"Pravda", May 21, 1972.

In accordance with a program for the further development of communication systems by using artificial earth satellites, the Soviet Union launched the Molniya-2 communication satellite into a high elliptical orbit on May 19, 1972. The Molniya-2 has on-board retransmission equipment working in the centimeter wave band.

The Molniya-2 communication satellite is designed for developing the long-range telephonic and telegraphic radio communication system in the Soviet Union, transmitting Soviet Central programs to points in the Orbita network, and for international cooperation.

The satellite was sent into an orbit with an apogee of 39,300 km in the Northern Hemisphere and a perigee of 460 km in the Southern Hemisphere.

The satellite's orbital period is 11 hours 45 minutes, the orbital inclination is 65.5°.

Apart from equipment for trarsmitting television programs and providing long-range multi-channel radio communications, the satellite has command and measurement equipment, and also systems which orientate it, correct its orbit and supply energy to it.

Communication sessions via the Molniya-2 satellite will be carried out according to a specific program.

TABLE 1: LAUNCHES OF SATELLITES OF THE METEOR SERIES DURING 1972

Numerical order	Launch date	Orbital period, min	Apogee, km	Perigee, km	Orbital inclination to the equatorial plane, degrees
1	30 March	102,6	903	878	81,2
2	30 June	103,0	929	897	81,2
3	27 October	102,6	904	893	81,2

TABLE 2: LAUNCHES OF SATELLITES OF THE MOLNIYA SERIES DURING 1972

Numerical order	Launch date	Name of vehicle	Orbital period, min	Apogee (in Northern Hemisphere), km	Perigee (in Southern Hemisphere), km	Orbital inclination to the equatorial plane, degrees
1	4 April	«Молния-1»	11hrs 45min	39 260	480	65,6
2	19 May	«Молния-2»	11 45	39 300	460	65 5
3	30 September	«Молния-2»	11 43	39 200	480	65,3
4	14 October	«Молния-1»	11 45	39 300	480	65,3
5	2 December	«Молния-1»	11 43	39 100	500	65,0
6	12 December	«Молния-2»	11 45	39 300	470	65 3

Key throughout table: a. Molniya

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III. LUNAR RESEARCH

A Glorious Victory in Space

"Pravda", March 3, 1972.

There has been a new victory in space -- the flight program /75
of the Luna-20 automatic station has been successfully completed. Launched on February 14 and reaching the vicinity of the moon, the station went into selenocentric orbit, after a series of maneuvers made a soft landing on the mountainous continental region of the moon for the first time, took a sample of soil and headed back towards earth. The station's re-entry vehicle successfully landed on February 25 in the designated area. A search group quickly found the "Luna parcel' in difficult meteorological conditions. Hence, another bright page in the history of space conquest was written. The scope for investigating heavenly bodies has been increased by using automatic control units.

The Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR, and the Council of Ministers of the USSR warmly congratulated scientists and designers, engineers, technicians and workers, collectives and organizations which took part in constructing the Luna-20 automatic station and brought lunar soil samples back to earth. "This is a new achievement for Soviet science and technology in lunar and

outer space research -- the result of the inspired work of the glorious working class, scientists, designers, engineers and technicians of our Socialist Motherland, greeting the 50th anniversary of the formation of the USSR," this was the content of the document.

Innovation and skill, these are the features which enabled the design of the Luna-20 and brought it into technical reality. We are indebted to the great skill of specialists of ground control services who accurately maneuvered the station during the whole flight, and especially during the soft landing in the mountainous region, directed the drilling work at a great distance and guided the rocket back to earth. All this showed the great potential of Soviet science and socialist industry.

Soviet astronautics has been noted for its desire to pave the way for space research from the first. The launch of the artificial earth satellite and the historic flight of Yu. A. Gagarin, the descent of man-made vehicles in the atmosphere of Venus and the transmission of scientific information from its surface, a soft landing of a vehicle on Mars -- all these and much more are achievements of Soviet science and technology and are chronicled in the knowledge of the universe and have a note "first achieved".

Soviet astronautics is contributing much to lunar discovery. Automatic stations, which went into selenocentric orbit, photographed the reverse side of the moon, made a soft landing on its surface and transmitted a "television report" from it, all bore the emblem of the Soviet Union. Automatic control units landed on /76

the moon the Lunokhod-1, the long-term self-propelled laboratory, allowing lunar samples to be taken without risking human life -- at first from the "Sea" plain, and later from the mountainous area. Soviet space technology, which has been widely acclaimed by the whole world, has become a powerful weapon in the research of distant regions of the solar system and its heavenly bodies, and is an excellent instrument for studying the earth for national economic needs in the interests of mankind. It has made a great contribution towards the development of world science.

Tasks accomplished by Soviet astronautics are becoming more important and crucial. Their very nature constantly requires the joint effort of workers of many branches and economic regions and the complex, systematic approach to planning and decision taking. Successes in this direction give an example of how one must combine the achievements of scientific and technical progress with practice and creative daring when introducing methods of modern scientific management.

The directives of the 24th Congress of the Communist Party of the Soviet Union layed down a wide program of scientific work in space. Among them are the development of long-range telephonic and telegraphic communication, television, weather forecasting and the study of natural resources, geographic research and the solution of other national economic problems by using satellites, and automatic and manned vehicles. Others are the continuation of basic research of the moon and planets of the solar system. The

flight of the Luna-20 once more shows the far-sighted and firmly-based belief of our specialists in developing automatic facilities for studying adjacent and far space.

Soviet people were well-satisfied with the news of this wonderful achievement of Soviet astronautics. They heartily greeted those who built the station and participated in the experiment, and hope that they will achieve new successes in space conquest. The Luna-20 flight inspires Soviet people, multiplies their efforts in the struggle for scientific and technical progress and the increase of production efficiency and for the continued strengthening of the economic and defensive might of the Soviet Union.

The Soviet "Lunar probe" caused great interest in friendly socialist countries, in the progressive society and in scientific circles throughout the whole world. Scientists, information agencies and the foreign press are giving good reports of its results. "A triumph for Soviet science", " a scientific event of outstanding importance", "the way has been cleared for the direct study of almost inaccessible regions of the moon" -- these are characteristic of the reports.

Near-earth orbits, the moon, Venus and Mars -- how far the "space hands" of Soviet people have stretched out in search of knowledge in an attempt to understand the laws of nature. All this was due to the constant attention of the Communist Party, the Socialist Government, and the nation as a whole for the conquest of space for friendly purposes, this is one of the forefronts of the scientific and technical revolution.

The assault on space frontiers continues. Kosmos automatic control units are being launched, -- there have already been 476 of them. Meteorological and communication satellites continue their watch. Delicate antennas are receiving signals from vehicles in Mars and lunar orbit. Participants in the new experiment, in a letter to the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supremen Soviet of the USSR, and the Council of Ministers of the USSR assured them that they will respond to the party's and government's concern and attention with new successes. May this be so!

Four Months in Near-Moon Orbit

"Pravda", January 30, 1972.

The long-range space communication center, 29. (TASS). For /77 months the Luna-19 automatic station has conducted research in selenocentric orbit. During this time it completed 1,358 revolutions around the moon.

Research into the moon's gravitational field by systematic, prolonged observations of its orbital evolution is being conducted on the results of radio technical measurement of the station's orbital parameters.

Continuous measurement of the characteristics of the interplanetary magnetic field near the moon is being made from near the station. In this way, it was determined that the field on the bright side of the moon is several times stronger than the

unperturbed magnetic field. At the same time, the magnetic field on the night side is considerably attenuated.

Both experiments were conducted to broaden the scientific concepts of the moon's internal formation. The study of characteristics of cosmic radiation in near-moon space is continuing. Simultaneously, identical measurement is being done by equipment on board the Mars-2 and Mars-3 automatic stations which are more than 200 million kilometers from the moon. Interesting, valuable scientific information has been obtained on the dynamics of change of intensity of cosmic radiation corpuscular beams. In particular, towards the end of last month there was a noticeable increase of intensity, exceeding its average value by approximately one million times.

As was suggested, this is the result of a powerful chromospheric solar flare and coincides with information of ground astronomical observations.

Apart from this research, the density of the meteorite shower in near-moon space is being measured.

The Luna-19 station continues its flight.

The Face of the Moon

B. Nepoklonov, a Candidate of Technical Sciences

"Izvestiya", January 29, 1972.

The scientific research program for the Luna-19 station includes photography of individual sections of the lunar surface.

Therefore, the station is equipped with two optical-mechanical television cameras. One feature of them is that scanning of the image along the line of flight is done by the station's own orbital motion.

On several orbital television panoramas one can see territory close to the near-equatorial central zone of the northern half of the moon's visible disc. When examining these pictures, one must note that large structural shapes of the lunar relief stand out very well: seas, continents, craters and fractures. Therefore, they can be used for studying the shape of the basic geological formations, the degree of destruction, the general nature of the relief, and for compiling information necessary for reconstructing the moon's history.

An interesting feature of the panoramas is a picture of craters of a similar age of the so-called Eratosthenes complex. This is the crater Eratosthenes itself (Fig. 12a), which gave its name to the complex, and the craters of Godin and Agrippa (Fig. 12b). Their general outstanding feature is the distinct profile contours, and the internal slopes of the craters are steeper than the external ones, and the bottom of the craters is lower than the surface surrounding them. Central hills rise up among the craters. There are projecting ledges on the internal slopes of the craters. The external slopes of the crater walls gradually merge into the fields of crater ejecta.

On Fig. 12a, powerful ejecta from the crater Eratosthenes in /78
the form of ridges and walls can be clearly seen at a distance of

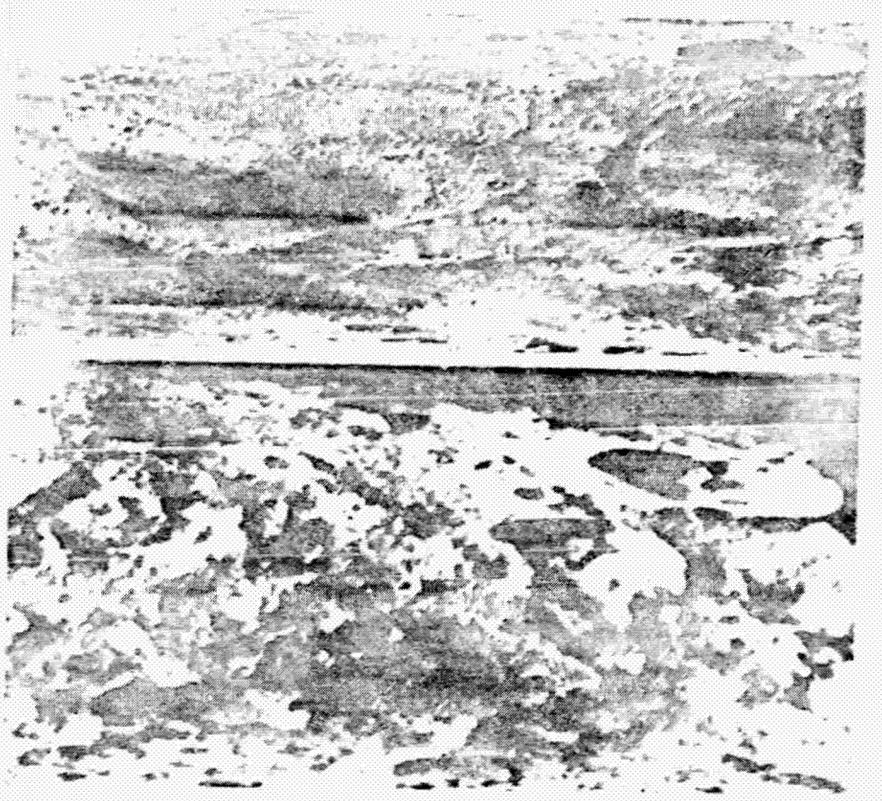

Fig. 12. Orbital panorama fragments. a - The region of the Sinus Aestuum with the crater of Eratosthenes; b - The craters of Godin and Agrippa.

30-50 km from the wall and gradually thinning they extend over the surrounding area. A feature of this ejecta is the absence of corona of light rays which are characteristic of craters of the Copernicus type which are visible from earth. This, and also the better preserved shape of the craters of the Copernicus complex, gives us reason to believe they are younger than craters of the Eratosthenes complex. Apparently, the crater of Eratosthenes, in its turn, was formed later than the Mare Imbrium and the cordilleras, visible in the upper part of Fig. 12a, which encircle it.

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In the central part of the panorama fragment (Fig. 12a) one can see the southern part of the Sinus Aestuum and the region of the Copernicus crater. They can be described by the amount of ejected material and differ in hilly relief and the amount of secondary craters. Among this ejecta one can clearly see a huge stone block several kilometers across. In this part of the picture, one can also see the typical ancient Stadius crater with broken remnants of a wall projecting through the compact cover of sea rock.

In this way, one of the youngest formations of the lunar surface, covering the most ancient, is depicted on fragments of the panorama.

Five Months in Flight

"Pravda", March 11, 1972.

The long-range space communication center, 10. (TASS). The Lune-19 automatic station has been carrying out scientific research in near-moon orbit for more than five months.

On March 10 at 1300 hours Moscow time the Luna-19 station completed 1,810 revolutions around the moon. During this time, 516 radio communication sessions were held with the station, during which trajectory measurement was done according to the satellite's orbital evolution for long-range research into the moon's gravitational field.

The data of systematic observations obtained were processed in the coordinating computer center at institutes of the Academy of Sciences of the USSR.

According to telemetering information, the station's on-board systems are working normally.

The flight of the Luna-19 Soviet automatic station continues.

The Moon in the Objective

TASS Pictorial Review

"Pravda", March 19, 1972.

The Luna-19 automatic station continues carrying out a program of complex research in selenocentric orbit. Apart from studying the moon's gravitational field, magnetic measurement and measurement of the characteristics of cosmic radiation, the station is carrying out selective panoramic television photography of the lunar surface. This is being done to accumulate material for comparative topographical and geological analysis of the surface and show the features of the spatial distribution of tectonic structures.

On the fragment shown (Fig. 13) of orbital perspective panoramas one can see extensive continental spaces in the area from the 30th to the 60th degree of south latitude and from the 20th to the 80th degree of east longitude. This area, on the edge of the lunar visible disc, has been insufficiently studied both by /80 ground telescopic photographs and by photographs obtained from

spacecraft. The photography was done near to the terminator line when the Sun was low above the local horizon. This allows one to interpret on the photograph individual, small details of the lunar surface relief. This region is characterized by large ancient craters with smooth floors belonging to the so-called Ptolemaeus complex.

Fig. 13. A panorama fragment of the Ptolemaeus complex.

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A Year in Near-Moon Orbit

"Pravda", October 4, 1972.

The long-range space communication center, 3. (TASS). The Soviet Luna-19 automatic station, launched on September 28, 1971, has been conducting scientific research in near-moon space for a year. During this period, the station completed more than 4,000 revolutions around the moon, more than 1,000 radio communication sessions were held with it, during the course of which control commands were given by on-board systems and scientific equipment, a check of their condition was made and information was obtained on scientific experiments conducted.

During the whole flight of the artificial lunar satellite radio technical measurement of the parameters of the trajectory of its motion were made to determine the orbital evolution. Measurement information is being used to determine the characteristics of the moon's gravitational field which are very important to improve scientific concepts of its evolution and structure.

Experiments were conducted from the automatic station into the research of near-moon space by a radio wave propagation method, and a study was made of the laws of reflection of radio waves by different portions of the moon's surface. Results obtained show that there is plasma which has been formed as the result of interaction of cosmic radiation with the moon's surface.

In accordance with the flight program the Luna-19 automatic station took television pictures with an optical-mechanical camera

with unidirectional scanning. This photography was also done to research into specific sections of the moon's surface to investigate the possibility of using orbital panoramas for navigating spacecraft.

Special equipment measured the spatial density of meteor particles near the moon. In particular, it was found that the spatial density of particles, not belonging to meteorite showers, is the same as that in interplanetary space.

One important result of the flight was the systematic information of corpuscular beams of solar and galactic cosmic radiations. More than ten significant flux increases of protons of solar cosmic rays with energies of greater than one million electron volts were recorded, and this is the result of powerful solar flares. The intensity of galactic beams at that time also underwent significant changes caused by active processes on the Sun.

Similar measurement was made by the Lunokhod self-propelled laboratory, the Venera-7, Venera-8, Mars-2 and Mars-3, the Prognoz and Prognoz-2 automatic stations in various areas of interplanetary space. In this way, a continuous check was kept of the radiation situation in outer space for two years. The results obtained give more information of the energy spectra, charging components of /81
cosmic rays, and the way in which they are propagated in the interplanetary medium.

During the whole flight the Luna-19 on-board systems and scientific equipment worked normally, and the projected program was carried out successfully.

The prolonged space experiment in near-moon orbit is nearing completion. Measurement data obtained during the flight is being processed and will be published.

A TASS Report: The Luna-20 Automatic Station in Flight

"Izvestiya", February 14, 1972.

In accordance with the outer space research program, on February 14, 1972 at 6 hours 28 minutes Moscow time the Soviet Union launched the Luna-20 automatic station.

The aim of the flight is to carry out further scientific research of the moon and near-moon space.

The station was launched towards the moon from an artificial earth satellite orbit and is moving in a trajectory close to the predicted one.

According to telemetering information, the station's on-board systems and units are working normally. A ground command and measurement complex is maintaining stable radio communication with the station. The coordinating computation center is processing incoming information.

A TASS Report: The Luna-20 Station in Near-Moon Orbit

"Pravda", February 19, 1972.

The flight of the Luna-20 automatic station continues. During the flight from earth to the moon, radio communication sessions were

held regularly with the station, during which the parameters of the movement trajectory were measured and a check was made of the station's on-board systems and units.

A flight path correction was made on February 15 to bring the station into the specified area of near-moon space.

The spacecraft was decelerated on February 18 during the flight to the moon, as a result of which it went into circular selenocentric orbit with the following parameters:

-- altitude above the moon's surface -- 100 km;

-- inclination to the lunar equatorial plane -- 65°;

-- orbital period around the moon -- 1 hour 58 minutes.

According to telemetering information, all the stations on-board systems are working normally.

The long-range space communication center is maintaining stable radio communication with the station. A coordinating computation center is processing the incoming information.

A TASS Report: The Luna-20 Automatic Station Has Made a Soft Landing on the Moon

"Pravda", February 23, 1972.

The Soviet Luna-20 automatic station made a soft landing on /82
the moon for the first time in the highland continental region. An important scientific and technical problem was solved for setting down equipment in a region with a complex terrain relief.

The Luna-20 automatic station landed on the moon's surface on February 21, 1972 at 22 hours 19 minutes Moscow time in a position

with selenographic coordinates: 3°32" north latitude and 56°33" east longitude.

As already reported, the Luna-20 was sent into selenocentric circular orbit on February 18.

On February 19 the station's movement was corrected, as a result of which it went into elliptic orbit with a maximum altitude above the moon's surface of 100 km and a minimum altitude of 21 km.

On February 21 at 22 hours 13 minutes the main retrofire motor was switched on to set the station down in the calculated position. The engine installation was switched off after 267 sec and the station was in free fall before reaching an altitude of 760 m.

The rest of the descent was made under control, during which the thrust of the main engine was changed by an automatic control system. At a height of 20 m from the moon's surface deceleration was done with a thruster.

The position where the Luna-20 landed is in a part of the lunar continent near the north-east tip of the Mare Fecunditatis. According to telemetering measurement, the on-board systems are working normally.

The Luna-20 has begun to carry out a work program on the moon's surface.

A Landing in the Lunar Highlands

A. Bazilevskiy

A Candidate of Geological and Mineralogical Sciences,
a scientific worker at the Space Research Institute of
the Academy of Sciences of the USSR.
"Izvestiya", February 22, 1972.

The Luna-20 landed in the highland region between the Mare Fecunditatis and the Mare Crisium on February 21 at 22 hours 19 minutes. The landing site is 130 km to the north of that where the Luna-16 made a moon landing, and in September 1970 sent back to earth a lunar soil sample from the Mare Fecunditatis. When approaching the landing area, the Luna-20 flew over the plain of the Mare Fecunditatis and, descending to approximately 35 km into the highland region, landed on the moon's surface several kilometers from the western edge of the crater wall of Apollonius C.

A landing in the highland region is technically extremely difficult. The station's control system for descent and deceleration must allow for the ruggedness of the terrain below the flight path, and the descent vehicle must be capable of landing on a rugged surface.

The first soft landing on the moon was made six years ago, in February 1966, by the Luna-9. Since then, much study has been made of the earth's natural satellite.

We now known that the plains of luna maria are extensive, hardened fields of basalt lava, covered with a layer of splintered rock, partly local, and partly carried from elsewhere. Impact and /83
explosive phenomena, linked with meteoritic bombardment of the

surface, are mainly responsible for the splintering of rocks on the lunar surface and the horizontal shift of material. Volcanic effusions in lunar maria, for the most part, took place approximately 3-3.5 billion years ago. Scientists learned of this as a result of Soviet and American space flights.

At the present time, it is interesting to study the highland regions during research into the moon. Judging by many signs, the highland region were formed before lunar maria, probably, during very early stages of the moon's evolution, 4-4.5 billion years ago. On earth, traces of events, taking place in similar early stages of the development of planetary bodies of the solar system, have been "obliterated" by active geological and biological processes. At the same time, information on the early stages of planet evolution, above all of the earth, is needed by scientists to understand the laws of development of planetary bodies.

The area where the Luna-20 landed is a typical example of a highland region. It is a small plateau-like elevation rising, on an average, 0.5-1 km above the Mare Fecunditatis. Its surface is covered by numerous craters. The number of craters with a diameter greater than a kilometer, in a unit of area surface (crater density) in the vicinity of the landing area, is approximately ten times greater than on the surface of the Mare Fecunditatis. To the west of the landing site is the Apollonius C. crater with a diameter of approximately 10 km. The density of small craters with diameters from several meters to several hundreds of meters in the landing site

area, judging by a number of signs, is rather less than on the surface of the Mare Fecunditatis.

The boundary of the Mare Fecunditatis and the highland region where Luna-20 landed has a clearly defined structural character. On photographs of this area of the moon's surface, taken from [illegible] spacecraft and during normal telescopic observations from earth, one can clearly see fractures in the lunar crust, which often form the natural boundary between the surfaces of the maria and the highlands. Sometimes, one can see how a part of a crater, at the edge of the highlands, has been pushed into the lunar crust and covered by lava filling the depression of the Mare Fecunditatis. Often in the area where the mare joins the highlands there are areas covered by characteristic dome-like elevations, presumably of volcanic origin.

The increased density of distribution of large craters in the highlands must mean that fragments of rock, ejected from a depth of several hundreds of meters to 1-3 km, form the splintered surface layer. In particular, lunar soil in the Luna-20 landing area was formed in a layer of ejecta from the crater Apollonius C., which is more than 1 km deep.

On the basis of analyzing photographs of the moon's surface, specialists in lunar geology believe that the depression in the Mare Fecunditatis is one of the oldest mare depressions on the moon. Judging by results of analysis of lunar soil samples collected by Luna-16, this depression was filled with basalt lava approximately 3.5 billion years ago. The highlands which surround the

Mare Fecunditatis are geologically older than the lava filling the mare depression. Therefore, it must be expected that rocks which were formed in the very early stages of the moon's evolution make up the geological structure in the area where the Luna-20 landed.

The Luna-20 experiments continue, but it is already quite /84 clear that this flight is a new stage in moon research. In clearly shows the efficiency of the method of lunar and planetary research by automatic facilities chosen by Soviet scientists.

The Path to the Lunar Highlands

A. Gurshteyn, a Candidate of
Physical and Mathematical Sciences

"Pravda", February 23, 1972.

Passing the sloping north-east tip of the depression of the Mare Fecunditatis and flying over, during the final stage of descent, at an altitude of more than 50 km above the surface of the lunar highlands, cut by ancient relief forms, the Luna-20 made a soft landing close to the small Apollonius C. crater. The moon landing site is in the southern area of the elongated highland plateau which separates the plain of the Mare Fecunditatis and the Mare Crisium. The prolonged controled descent of an automatic station and the precision landing in the prescribed area of the lunar highlands was achieved for the first time.

The landing of an automatic station on the lunar highlands is important for studying the lunar surface, and is new proof of

the inexhaustible possibilities which exist when using various automatic space vehicles for further research of the moon and planets.

The soft landing of the automatic station in the highlands is the solution of an important scientific and technical problem, and opens up new possibilities for further comprehensive study of the moon. In February 1966 the Soviet Luna-9 automatic station made a soft landing for the first time on the surface of the planet and transmitted television pictures of a "lunar stone" back to earth. It disclosed the secret on the formation of the lunar surface. In April 1966 the Luna-10 became the first artificial satellite of the moon and began the detailed study of the features of its gravitational field. A gamma spectrometer in the Luna-10 obtained the first information on the mineralogical composition of extensive areas of the lunar surface. The Luna-13 automatic station, equipped with the necessary instruments, studied directly the physical and mechanical properties of the lunar surface. Soviet automatic stations of the Luna and Zond series repeatedly photographed different areas of the moon on different scales and transmitted back to earth a wealth of information on the structural features of the lunar surface.

An important stage in research, design and construction work in rocket and space technology was the production of a unitized landing platform which was successfully used in Luna-16 and Luna-17 flights. The Luna-16 automatically brought back to earth a sample of lunar regolith from the Mare Fecunditatis. This station made

a soft landing during lunar night 60 hours after sunset, when the temperature of the lunar surface was already tens of degrees below zero. It is still impossible to carry out such scientific problems in lunar night with manned spacecraft.

The Luna-17 station set down on the moon a mobile scientific laboratory -- the automatic Lunokhod-1. It actively researched the surface structure of the Mare Imbrium for a considerable length of time. The Lunokhod-1 was also equipped with scientific instruments for studying outer space. The length of active work, characteristic of modern automatic systems, cannot be accomplished during manned flights to the moon. /85

A wealth of new information on the moon, collected over the years as a result of the rapid development of astronautics, has given much new important scientific data. The use of sequence photography of the far side of the moon, never seen from earth, showed differences in its visible and reverse hemispheres. Up until now, photographs were the basis of several published maps of the far side of the moon. In 1970, the International Astronomical Union gave 500 new names to recently discovered formations on the moon.

Over the years, experimental data was obtained on the structure of the moon's surface on millimeter, centimeter, and meter scales. Similar information was obtained on the physical and physical and mechanical properties of various parts of the moon's surface. This information destroyed the legend of fine, flowing lunar dust. Both direct and indirect methods were used for

determining the chemical composition of the soil of various regions of the lunar surface and bringing samples back to earth, and information was obtained on their absolute age. This research led to further development work in lunar geochemistry.

Comprehensive study of the features of the moon's gravitational field, together with subsequent work in seismometry and magnetometry, laid the foundation for development work in lunar geophysics. Prolonged measurement of the orbital evolution of an artificial satellite of the moon, the Luna-19, contributed to research into the moon's gravitational field.

Recently, information obtained made it possible to solve fundamental problems of the origin and evolution both of the moon and the solar system as a whole, on a completely new level. Hence, it is now interesting to study lunar highlands.

There is reason to suppose that lunar highlands are formations of the oldest pregeological stage of the moon's development -- the condensation stage of lunar matter from a primary, protoplanetary gas-dust cloud. Information on the structure of lunar highlands can disclose the secret of the early stages of development of the solar system.

According to prevailing scientific opinions, the lunar maria are gigantic hollows, filled by basalt lava flows, formed during partial fusion of primary lunar rock. The lava has indirect signs characterizing the features of the moon's initial "protomatter". But modern science needs direct information on the nature of lunar

highlands for reliable conclusions to be made on the origin of our natural satellite and its evolution stages. However, their surface is extremely rugged and landing spacecraft on them is a difficult task.

After a space flight of 7.5 days, the Luna-20 landed approximately 120 km to the north of the area from which the Soviet Luna-16 had brought soil samples to earth. The ancient surface of the highland plateau in the landing area of Luna-20 rises approximately 1 km above the mean level of the Mare Fecunditatis. The surface is sloping and undulating, pitted with numerous craters up to several hundreds of meters in diameter. The difficulty of landing a station here is aggravated since there are many tectonic /86 fractures on the surface of the highland plateau between the Mare Fecunditatis and the Mare Crisium. The boundary between the mare and the highlands in the landing area is narrow and, apparently, also tectonic.

The landing of the Luna-20 on the lunar highlands is a new important step for science and technology. It opens up wide possibilties for flights into complex and most interesting, from the scientific point of view, areas of the moon.

A TASS Report: A Spacecraft Returns

"Pravda", February 24, 1972.

The Soviet automatic station has carried out its work program on the moon.

On February 23, 1972, the spacecraft was launched from its landing stage towards earth. The re-entry vehicle contains soil samples collected from the moon's almost inaccessible highlands.

As already reported, the Luna-20 made a soft landing in the highland region between the Mare Fecunditatis and the Mare Crisium on February 21, 1972 at 22 hours 19 minutes. After landing, the station's on-board systems were checked and its position was determined on the lunar surface. A telephotometric device transmitted to earth pictures of the lunar surface, and the place for collecting lunar rock samples was chosen accordingly. Then, the collection of samples began at a command from earth.

The soil-collection device drilled the lunar soil and collected rock samples. Due to the increased soil resistance, the drilling was done in several stages and the drill stopped at intervals. The samples collected were placed into a container in the spacecraft and sealed.

The spacecraft was launched from its landing stage on the lunar surface at a command from the on-board programmer and timing device, on February 23, 1972 at 1 hour 58 minutes Moscow time. The trajectory parameters were close to the calculated ones.

During the final stage of the flight from the moon to earth, the re-entry vehicle was detached and on February 25, 1972 will enter the dense atmospheric layers, will be decelerated aerodynamically and carry out a soft landing using a parachute system.

During the flight towards earth trajectory measurement will be made during transmission sessions with the spacecraft to

determine the coordinates of the landing area. Search facilities have been placed on the required readiness state.

Drilling in the Highland Region

D. Dryuchenko, Engineer

"Pravda", February 24, 1972.

The beginning of experiments for the direct study of the physical and mechanical properties of the lunar surface was made possible by the successful landing of the Soviet Luna-13. It used an automatic soil measuring device, a penetrometer and a radiation densitometer which were set up on the surface by special flexible /87 rods beyond the area damaged when the station landed.

After the Luna-13, the American Surveyor vehicles also landed automatic devices on the moon's surface to determine the soil's stability.

As aresult of these experiments it was found that the moon's surface where automatic stations would land was covered with a layer of loosely-packed hiatal material. Its basic physical and mechanical properties were also determined to a depth of approximately 2-20 cm. Naturally, scientists are interested in the way in which properties of this material change according to depth, its stratification strength, and where the hard rock begins and what form they take. This lunar bedrock has not lost its initial properties, as happened with the surface layers which were subjected to

the destructive effect of many factors over the centuries, principally, cosmic radiation and meteoritic bombardment.

Therefore, the bedrock can answer many questions concerning the origin of the moon, the earth and other planets of the solar system.

Can we penetrate deep into the moon by using such methods? On earth this would be simple. The earth's suface layer can be opened by various methods, beginning with a spade and ending with a directed explosion. Normally, bore holes are sunk to the required depth and samples of rock taken from them. It is difficult to send an excavator there, but at the moment this is not required. It is too early to use explosions, since holes must be made and packed with explosives. After studying many methods, specialists have concluded that at this stage of development the most effective and economic method of penetrating the moon's surface is to sink a hole. There are many methods of doing this. Which is the best for lunar conditions?

One can adopt the normal drilling method widely used on earth. But how does one drill and extract the rock from the hole? This cannot be done with water since it will freeze or evaporate. The use of gas is complicated and expensive. And how does one cool the cutting bit? An electric-arc or plasma method exists. However, its use involves many problems, the main one being that such a drillhole is unsuitable for further research -- its walls will melt, the rock formation will disintegrate and, most important, it will be impossible to obtain a rock sample.

Undoubtedly, in the future all these methods will be used on the moon. Now, at the beginning of the study, when much is still unclear and the weight of equipment sent to the moon is reckoned in grams, one must choose the most efficient, economic and general purpose method. This method of drilling is a modification of the core drilling method. Incidentally, it satisfies two diametrically opposed problems, one of which is the need to take a monolithic core, the other to extract cohesionless soil.

In this way, the further development of automation methods for investigating the moon's surface layer has brought about the development of special drilling equipment. Equipment of this kind was used by the Luna-16 for sampling soil. As is known, the Luna-16 made a soft landing in the area of Mare Fecunditatis in September 1970. As a result of this successfully conducted experiment, a /88
soil sample was taken from a depth of 350 mm and returned to earth.

The next step is to bring back to earth lunar bedrock samples for study. For this purpose, the Luna-20 containing drilling equipment, was launched on February 14, 1972.

As already said, the designers from the very beginning, met problems concerning the various requirements of scientists for a future soil sampling device. To satisfy these demands, a complex drilling unit must work in all types of rock and collect both cohesionless soil and hard, basalt type rock. The sampling must be done so that the natural formation is destroyed as little as possible. As a result of long, persistent search an optimum solution

was found: the equipment must operate on the percussion-rotary drilling principle with an angular face and subsequent withdrawal of the drilled work column -- the core. Until now, the problem of producing such a drilling implement, capable of extracting during one cutting hard, monolithic and cohensionless rock, has not been solved.

Experiments in rock on earth, having approximate physical and mechanical properties to those on the moon, and also those carried out by Luna-16 showed that the greatest effect on the drilling equipment was caused by its own temperature, and not that of the soil. Therefore, to maintain the serviceability of the drilling equipment in extreme temperature conditions, it was decided to provide the body with heat insulation. Apart from this, it was found that in a very high space vacuum, so-called agglutination of adjoining metal surfaces or the adherence of tiny lunar soil particles to them can take place under the influence of intermolecular forces. To prevent this, the drilling equipment was hermetically sealed. It was only unsealed just before work began. Lubrication of the working mechanisms was done during drilling by an "oily fog", that is, a substance evaporating in a vacuum. Apart from this, some friction surfaces were covered with a special coating which reduced friction in a vacuum. All this allowed the equipment to operate reliably in difficult lunar conditions.

This experiment showed once more the great possibilities for automatic control units when investigating the moon and planets. In the future, scientists will be able to tell from which rock the

moon is made and its extent. Apart from their purely scientific value, these questions can be of an applied nature. One may need to know how these rocks developed, could one build on them, and could they be used for different purposes. These questions can only be answered after geological cross sections have been made by using drillholes, from which investigated rock samples are extracted from different levels.

Therefore, the first drilling equipment will be automatic and capable of penetrating to great depths. This will give engineers and designers many problems. Materials must be made which are suitable for a rock-breaking instrument, and the amount of energy expended when cutting into lunar rock must be calculated. Apart from this, there is the complex question of replacing the instrument when it is put out of action and building up drill rods as the depth increases. All of this must be done automatically.

However, there is no doubt that designers, in close cooperation with scientists will successfully deal with these problems. The moon will give up more of its secrets.

Automatic Control Units Storm the Moon

Professor P. El'yasberg

"Pravda", February 25, 1972.

These years will go down in scientific history as the time of /89 intensive lunar research. Astronauts and automatic stations have already obtained information which has significantly broadened our

former concepts of the moon. Special interest today is being paid to the research into lunar rock samples brought back to earth.

These samples have only been taken from a few points on the lunar surface. But how varied it is! Therefore, it is extremely interesting to research into lunar rock samples from different areas. But how can we obtain them? The flight of the Luna-16 which automatically solved a whole series of problems of landing on a specified area of the moon's surface, collecting soil samples and returning to earth from the moon, demonstrated, perhaps, the most advantageous method today for solving this problem. The most advantageous, but not easy.

The first difficulty is the launch from earth. To launch a modern spacecraft one needs heavy, expensive material and a series of stationary facilities. On the other hand, the most advantageous flight path from earth to the moon depends on the relative position of these two heavenly bodies. The start point on earth varies at different moments of time. To avoid moving the launch position, the vehicle is sent into its flight path to the moon (just as in the flight path to the planets) in two stages. In the first, the vehicle is put into artificial earth satellite orbit, and then shifted from this orbit to its flight path towards the moon. The launch time from earth and the satellite's orbits are chosen so that the beginning of the earth-moon trajectory passes through a specified point. The earth's rotation and the satellite's motion in orbit are used here.

The second difficulty is the need to land on a previously specified region of the moon -- from the surface of which a soil sample will be taken. Apart from this, it is limited to a safe landing and launch. Therefore, this value does not exceed several kilometers. To land in a certain region from earth -- at a distance of approximately 400,000 km -- is as difficult as hitting a moving bear at a distance of 40 km with a pellet. The trajectory must be corrected several times during the flight to achieve the required accuracy. Therefore, directly after the vehicle goes into orbit, ground tracking stations begin working. They measure its range, movement and angular position. This information is fed into the ground coordinating computation center. Here, computers determine the actual trajectory and its deviation from the predicted one. The size and direction of the corrected impulse is also calculated.

This information is transmitted to the rocket. According to these orders, it turns so that its engine is pointing in the right direction. After this, at strictly determined moments of time the engine is switched on and off. As a result, the rocket shifts to a new, corrected trajectory. During a flight to the moon, a correction of this type can be made several times. The first corrects large deviations from the target; subsequent ones correct possible errors of the first.

However, there are no limitations. In spite of the corrections made, it is impossible to achieve the required accuracy for a direct landing on the moon. Apart from this, a direct landing is simply

impossible in all regions: for example, it is much more difficult to land on the far side of the moon. Therefore, when heading towards the moon, a rocket is turned into its artificial satellite orbit beforehand. For this, one must reduce the flight speed. /90 Otherwise, the rocket will fly past the moon and begin to move away from it in a hyperbolic trajectory. The time, size and direction of the appropriate retard impulse are also determined at the coordinating computation center, after which the appropriate orders are transmitted to the rocket.

After going into lunar satellite orbit, the rocket's motion is again measured and its actual trajectory is determined. One or several maneuvers are required so that the lunar station passes exactly above its target at the required altitude. After this, the retrorocket is switched on.

Landing an automatic station on the moon's surface is an extremely difficult and responsible operation and means the success of the whole experiment. As is known, the moon has no atmosphere. Therefore, parachutes cannot be used and deceleration is done by engines. The initial speed, exceeding 1.5 km/sec must be reduced to zero. It must be noted that when the automatic station is approaching the moon's surface there is no time to transmit commands from earth. Therefore, control of the retrorockets during the final stage is transmitted by automatic self-contained devices on board the station. Measurement of the distance to the lunar surface is made with an altimeter, and according to this information the

on-board computer automatically gives commands for switching on and switching off the engines.

After taking soil samples and conducting scientific experiments, the lunar station prepares to return to earth. One final crucial operation remains: the return flight and a soft landing on earth. For a number of reasons, this part of the flight differs considerably from the earth-moon trajectory. Firstly, the earth is many times larger than the moon and its powerful gravitation draws all the possible return trajectories into a narrow beam. This considerably eliminates the effect of large errors which can occur during a launch from the moon. Secondly, when returning it is simpler to select a landing site: the earth has many more extensive even areas where a landing is completely safe. Finally, parachutes can be used since there is a powerful atmosphere.

Therefore, there can be a direct flight from the moon to earth. The problem here is to align the engine before launch from the moon in order to produce the required take-off pulse, and to switch on and off the propulsion system at accurately prescribed moments of time. After the launch, the task of the coordinating computation center is to determine the actual flight path according to measurement data and to specify the landing site in order to give instructions to search groups.

In this way, the flight of automatic stations, designed for bringing back lunar rock samples to earth, requires the spacecraft to carry out a series of complex maneuvers faultlessly. This can only be done when there is close cooperation between ground

command and computer services and automatic devices on board the spacecraft. Flights of Luna-16 and Luna-20 show the high level of development of Soviet space technology. These flights are the result of the selfless labor of a large team of specialists in various fields.

Secrets of Lunar Soil

V. Shvarev

A Candidate of Technical Sciences, Sector Manager at the Space Research Institute of the Academy of Sciences of the USSR

"Sotsialisticheskiya industriya", February 25, 1972.

Only six years have passed since a Soviet automatic station /91 made the first soft landing on the moon. Research into the moon is continuing successfully. Great interest is being shown in studying the mechanical properties of lunar rock and also problems of working with it with machines and instruments.

How strong is lunar rock and soil? These questions must be dealt with before moving on the moon or drilling into it. Is the soil dust, sand or hard rock? What can we expect when machines and instruments come into contact with the soil: will they adhere or, on the other hand, slip, or will there even be electrification? How will the surface react to drilling?

These and many other questions are worrying scientists and designers creating lunar equipment.

We already know that lunar soil is strong enough for spacecraft to land and for a Moon research vehicle to carry out

movement. Despite the fears of many scientists and specialists, there was no noticeable soil adhesion to instruments.

However, something else is known: the strength of lunar soil changes significantly. In many cases this causes puncturing and subsidence even when there are small loads.

At the same time, American astronauts could not sink a flag staff to a depth of more than 15 cm, when they met compact, hard rock. Drilling by the Soviet Luna-16 showed a relatively soft rock to a depth of 35 cm. There are also cases when relatively large "stones" in the path of the Lunokhod-1 disintigrated under its wheels.

Therefore, it follows that the lunar regolith (soil surface layer), consisting of small particles bound to each other, is very porous and is easily transformed to fine dust even by small loads, and this dust can penetrate apertures and gaps in technical instruments. When the Lunokhod-1 was in motion, side by side with the normal, calculated cross-country ability there were cases when its wheel slipped on relatively gently sloping areas.

It is obvious that the lunar soil still has some secrets and surprises. Careful study of all its features will allow scientists and designers to find new, unexpected and inadmissible engineering solutions for ground conditions.

Mainly, the designer must know the complex of parameters of the strength and friction of the soil. The first group of these parameters is the ability to withstand static and dynamic loads, and also its affinity to strain and compression. The second

group is characterized by starting and friction coefficients when the soil comes into contact with different equipment, and its adhesiveness.

We must remember that instruments on the moon operate in less gravity in a vacuum.

Less gravitation means that the resistance force when starting up and also the frictional force when slipping, occurring during braking, is much more noticeable on the moon. These forces depend on the weight of the moving body, which, on the moon, is approximately six times less than on earth. As a result, with wheeled and tracked chassis, contact with the surface is reduced and this means slipping and the braking distance must be increased.

In a superhigh vacuum, the contact of solid bodies can cause /92
adhesion, especially when the contact is accompanied by the relative slipping of bodies. This tendency is also seen on the ground, when contacting surfaces are covered with fatty or oxide films. In fact, the interaction of bodies, in essence, takes place through a layer of "lubrication" which prevents agglutination and damage to the contact surface.

In a vacuum this is much more complex. There is no normal lubrication, and as a result, there is intense adhesion of different surfaces.

The lunar soil samples brought back by Luna-16 were examined in order to study the above parameters. Simultaneously, experiments were conducted on rock from earth which, according to scientists, had similar properties to lunar samples.

On the ground there are standard instruments which, if one has several hundred grams of matter, can quickly and reliably determine the parameters which interest scientists.

However, when conducting this research, one must house the equipment in conditions close to those on the moon. What is the result of this? As soon as a ground instrument enters a high vacuum it stops operating. In a vacuum all cogs, bearings and cams become jammed. The reason for this is the instantaneous evaporation of lubrication. One can adopt extreme measures: do not use lubrication and operate the instrument "dry". Then it will only work for a few hours.

An original testing facility was developed for examining lunar soil. One could create actual lunar temperature conditions on all samples tested. This was done by using liquid nitrogen with a temperature of -196°, and a special heater.

The testing facility examined 14 materials: from rubber and skin to hard alloys used in space technology. In each case, the friction coefficients on lunar soil varied little from the friction coefficient on earth andesitic-basalt sand or crushed basalt. This similarity is very important since it will be possible to develop lunar equipment on earth.

The study of lunar soil in natural-scale ground conditions is continuing successfully. We have just witnessed the most recent success in the discovery of distant worlds. The Soviet Luna-20 station is successfully carrying out its work program on

the moon and will bring back to earth new soil samples, this time from the almost inaccessible highland region near the Mare Fecunditatis.

Space Robots

G. Petrov, Academician

"Pravda", February 26, 1972.

The Soviet Union has developed a unitized automatic platform which can land various types of equipment on the moon.

This unitized platform was first used in 1970, when the Luna-16 was sent to the moon. The station had drilling equipment with manipulators, capable of placing a lunar soil sample into the container of the vehicle which was automatically sent back to earth. This experiment was successfylly completed on September 24, 1970. /93 Two months later a new experiment was conducted. A platform, differing from the first in a number of details in the tranportable equipment, set down on the moon the Lunokhod-1, a mobile automatic laboratory.

This mobile laboratory, weighing on earth 700 kg, was very mobile and successfully climbed slopes with an inclination of more than 30°. It could operate actively on the moon for many months and contained a considerable number of instruments. Various methods of navigation were also tested.

The success of the experiments conducted will provide the base for setting up outer space research programs. Among them will

be experiments to study the origin of the solar system and its evolution.

For example, bringing back to earth rock samples from various points on the moon. Mainly, one must determine the age of rock and the time it has been on the moon's surface.

It is scientifically important to investigate the internal structure of the moon. This includes prolonged study of the natural seismicity of the moon by using seismometers set up in different regions, and automatic, independent determination of coordinates (latitudes and longitudes) of a point on the moon's surface with a high degree of accuracy. One can study the motion of the moon's axis of rotation in its body and determine anomalies of speed of the axial rotation for calculating the so-called Love numbers, characterizing the viscosity of the body of the moon. Similar experiments can be conducted by setting up a telescope with a special electronic unit near the equator. This instrument, designed for observing the stars, will reach an automatic control unit on the moon.

An important problem is the study of the moon's electrical conductivity at depths of from 3-5 to 400-600 km. To do this, one must register in parallel the electrical and magnetic fields on the moon's surface, and at an altitude of 50-100 km above it. Research into the moon's internal electrical conductivity will allow us to determine the temperature and the approximate chemical composition to depths of several hundreds of kilometers.

The moon's surface, unprotected by atmosphere, is continually bombarded by meteorites of all sizes. Consequently, the mechanical structure of the upper layer (regolith) is the result of this bombardment. Equipment of the Lunokhod-1 type will allow special experiments to be conducted for studying the flux of the hard component of interplanetary matter in a wide energy spectrum and over time. After 6-7 months of operation, the self-propelled equipment can give complete information on the distribution and shape of craters, measuring from 10 cm to tens of meters over a considerable area. Preliminary processing of data, obtained by the Lunokhod-1, showed that in a number of cases one could determine which stones belonged to ejecta from a certain crater. This will enable us to evaluate the absolute age of a crater.

Determining the amount of time which rock has been on the moon's surface will allow us to measure the activity of cosmogonic isotopes directly on the moon's surface. The solution of this problem has certain difficulties, but it is worth trying to overcome them. The comparison of even a few time calculations with the geometric characteristics of primary craters will allow us to /94 determine the dependence of these characteristics on time. By studying craters of different dimensions in this way, one can determine the change over time of the total shower and meteorite spectrum in those regions of the solar system where the moon is. The success of this, to a great extent, depends on knowledge of an impact with great speed.

Another important factor in the experiment program on the moon is research by using automatic lunar satellites. The aim of these experiments is the detailed study of the gravitational field and the shape of the moon and variations of the magnetic field close to it. Another interesting experiment is observing the present meteorite shower on the moon's night side.

Information obtained by automatic vehicles on the moon is very extensive. There is no doubt that discoveries made by automatic control units will be very important in various spheres of studying the universe, especially in reconstructing the history of the development of our planetary system. The Luna-20 flight certainly confirms this.

A TASS Report: An Outstanding Space Experiment Is Completed!

"Pravda", February 27, 1972.

Soviet space science and technology has achieved a new victory in lunar research. The flight program of the Luna-20 has been successfully completed.

On February 25, 1972 the re-entry vehicle of the Luna-20 landed in the predicted area of the Soviet Union. Another task in lunar study has been successfully completed.

Samples of lunar soil from the almost inaccessible highland region of the moon were brought back to earth.

The complex space experiment took place in several stages. The Luna-20 was launched on February 14, 1972. After 105 hours of

space flight, the station went into selenocentric orbit. A correction was made on February 19 to land it on the predicted region of the moon.

On February 21 at 22 hours 19 minutes Moscow time the Luna-20 made a soft landing in the highland region between the Mare Fecunditatis and the Mare Crisium. The scientific and technical problem of landing an automatic vehicle in an area with a rugged surface was solved successfully.

After landing and checking the on-board systems the telephotometric equipment was switched on. Pictures of the moon's surface obtained by them allow a site to be chosen for soil sampling. The whole soil sampling operation was done by commands from earth. The soil collection equipment drilled and selected lunar soil samples, and afterwards they were placed in a container in the re-entry vehicle and sealed.

While the station was working on the moon its coordinates were determined and launch preparations were made.

On February 23 at 1 hour 58 minutes Moscow time, the spacecraft with the re-entry vehicle left the moon using the landing stage as a platform.

During the flight from the moon to earth, ground command and measurement stations, during radio communication sessions, received telemetering information and carried out trajectory measurement. This information was processed in the coordinating computation center to check the on-board systems and the actual flight path.

On February 25, the Luna-20 approached the earth with an escape velocity. The re-entry vehicle was separated from the spacecraft at the estimated time. After this, ground radar tracked the flight of the re-entry vehicle until it landed on earth. /95

Aerodynamic braking was begun when the re-entry vehicle entered the earth's dense atmospheric layers. During the final stage, the parachute system was used, and at 22 hours 12 minutes Moscow time the re-entry vehicle landed accurately at the estimated area 40 km northwest of the town of Dzezkazgan in the Kazakh SSR.

The search team, in spite of the exceptionally unfavorable weather conditions: strong wind, snow storm and low cloud, brought back the re-entry vehicle.

All the phases of the complex space experiment -- the vehicle's flight to the moon and selenocentric orbit, the soft landing on the surface, soil collection, the launch from the moon and the return to earth -- were carried out according to the program.

Lunar soil samples brought back by the spacecraft from the highland region of the moon will be sent to the Academy of Sciences of the USSR for scientific research. The study and analysis of a soil sample from a new area of the moon will widen our knowledge of the nature and evolution of the moon.

Results of the examination of the lunar soil samples will be published.

The flight of the Soviet Luna-20 once more showed the great possibilities for investigating the moon and the planets by using

automatic vehicles, and a new page was written in the history of world astronautics.

Drilling in the Lunar Highlands[1]

V. Vasil'yev, Engineer

"Nedelya", No. 9, February 21-27, 1972.

The launch vehicle has finished its work. It sent the station (Figs. 14, 15) into the planned trajectory and with its last effort guided the automatic control unit to the moon. The unitized

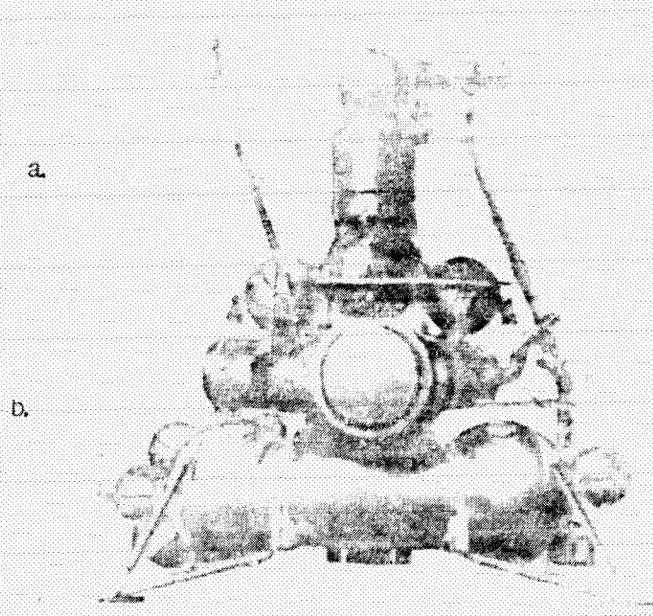

Fig. 14. The Luna-20 automatic station. 1 - Re-entry vehicle; 2 - Driling equipment; 3 - Drilling equipment rod; 4 - Telephotometer. a. Moon-earth rocket; b. Landing stage.

1 References to the figures (photographs), not shown in the article, but published by TASS in the Central Press during the flight of the Luna-20, have been added according to the editor's text. (Editor's note).

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Fig. 15. The state emblem of the USSR and a pennant left by the Luna-20 automatic station.

landing stage, freed from the control of its carrier, began to carry out its work.

Similar machines had already landed twice on the moon. One of them set down the Luna-16 in the Mare Fecunditatis, and the other landed the Lunokhod-1 in the Mare Imbrium. The task of this landing vehicle was more complicated: it was to make a landing in the almost inaccessible highland region.

The vehicle's flight schedule was a strict one. Numerous communication sessions with the earth, trajectory correction sessions, and the preparation of all the systems for its work on the moon -- these were the key moments during the earth-moon flight (Fig. 16).

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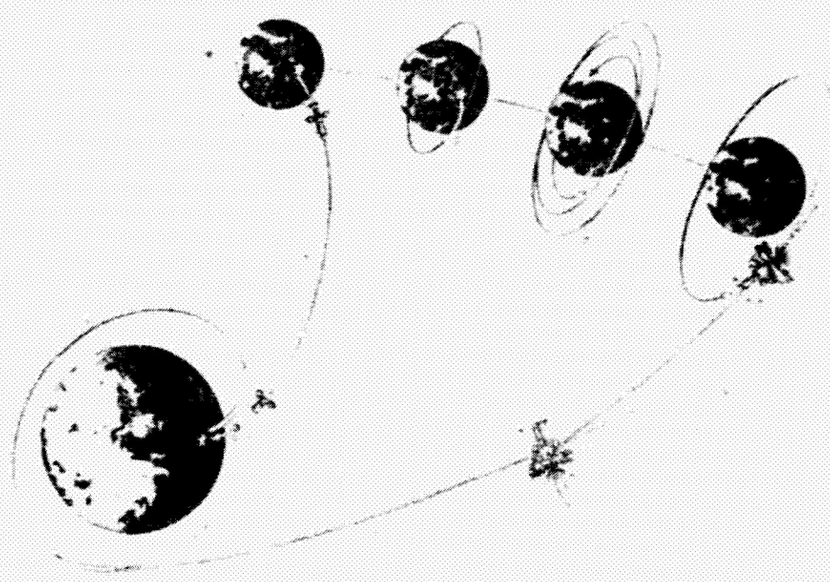

Fig. 16. A diagram of the Luna-20 flight. 1 - Sent into artificial earth satellite orbit; 2 - Flight in artificial earth satellite orbit; 3 - Boost; 4 - Earth-moon flight route; 5 - Correction; 6 - Deceleration and entry into artificial lunar satellite orbit; 7 - Lunar orbit; 8 - Maneuvering in near-moon orbit; 9 - Deceleration and soft landing; 10 - Launch from the moon's surface; 11 - Moon-earth flight route; 12 - Separation of re-entry vehicle from the rocket.

Deceleration begins when the vehicle passes the pericenter of its orbit (Fig. 17). From this altitude, for the Luna-20 it is 21 km, the station makes a steep descent. After 4.5 min the engine is switched off. At this time the altitude is just over /97 2 km. The Luna-20 was in free fall to a distance of 760 m. Then, the main engine was again switched on. The two thrusters which landed the vehicle at almost zero speed were used at a height of 20 m above the surface. The unitized landing stage had carried out its task. At the last tense moment a signal was sent to earth that the vehicle's shock supports had touched lunar soil (Fig. 18).

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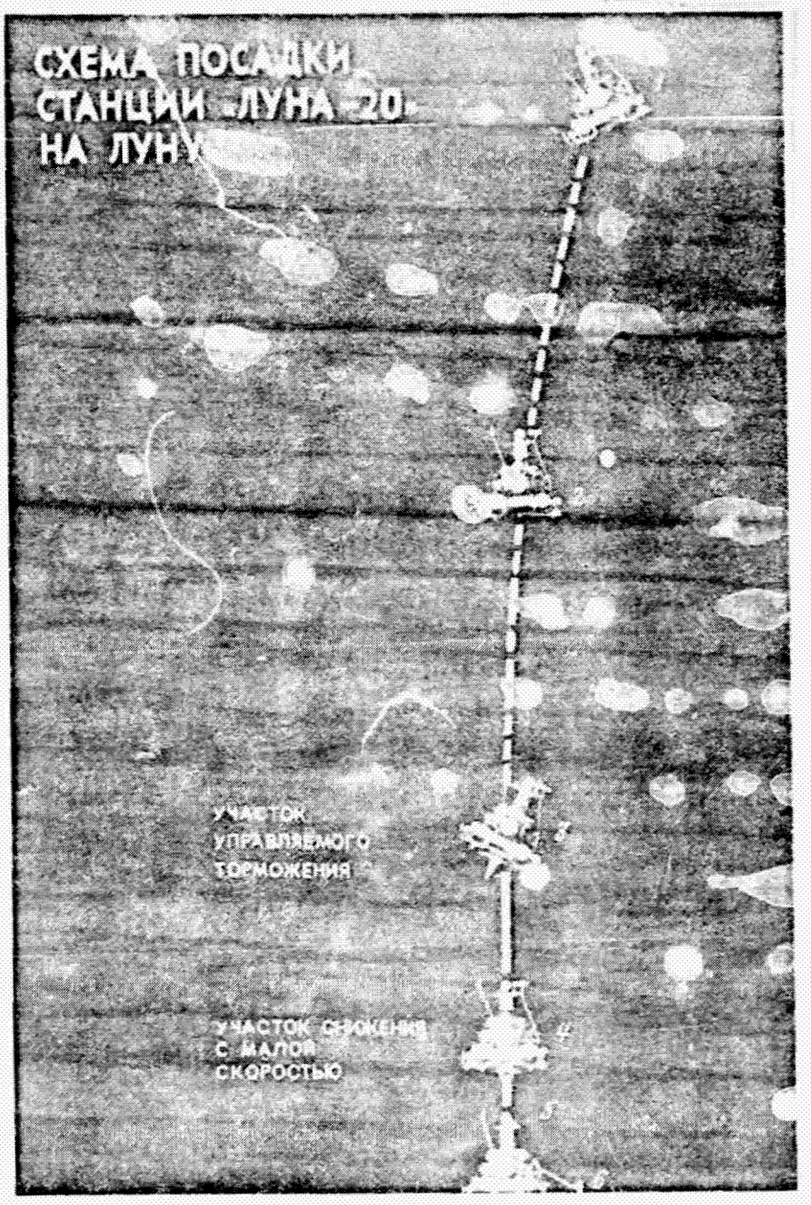

a

b

c

Fig. 17. A diagram of the landing of the Luna-20 station on the moon. 1 - Cut-off of propulsion system; 2 - End of station's turn; switch-on of radio altimeter and velocimeter; 3 - Switch-on of main engines; 4 - Switch-off of main engine; 5 - Switch-on of thrusters; 6 - Switch-off of thrusters. a. A diagram of the landing of the Luna-20 station on the moon; b. Controlled braking portion; c. Slow speed descent portion.

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Fig. 18. A map of the section of the moon where the Soviet Luna-16 and Luna-20 automatic stations landed. a. Luna.

Now the main scientific part of the flight program has begun. Two telephotometers were switched on. By using these, specialists at the long-range space communication center examined the surrounding area. Then a drilling site is chosen. A long mechanical rod, controlled from earth, carefully places on the soil a cylinder

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containing the drilling equipment. A motor is switched on an the drill begins to bore a soil column. The first centimeters are drilled quickly and easily but with depth the resistance to drilling increases. However, all this has been allowed for in the drilling machine's construction. The operator switches on another mechanical drive hich begins to raise and lower the drill. The hard layer gives way to the instrument. A hole is now drilled to the required depth and drilling ceases (Figs. 19-20). A special

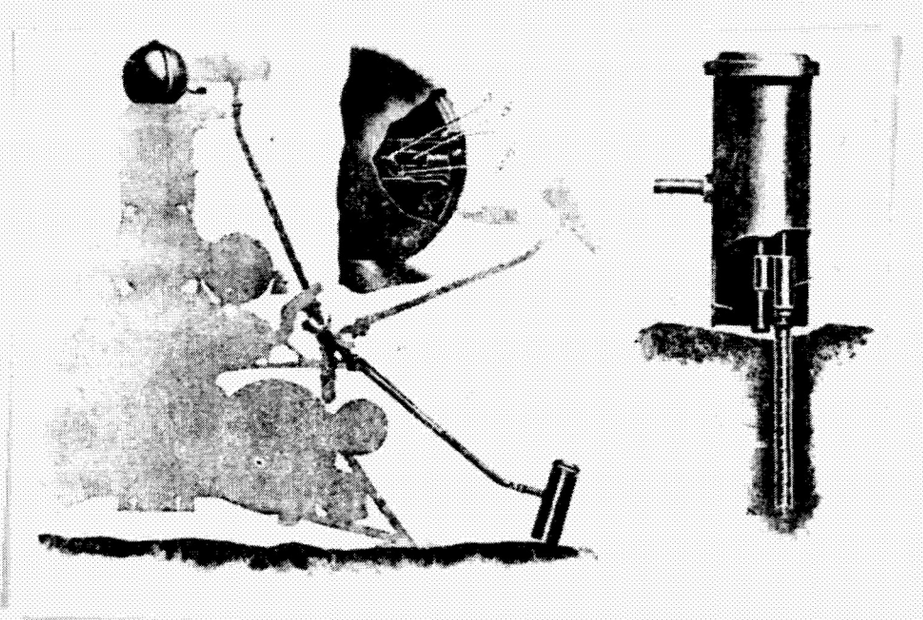

Fig. 19. A diagram of the Luna-20 automatic station's soil collection device. 1 - Re-entry vehicle; 2 - Initial position of rod and drilling machine; 3 - Arm damper; 4 - Operational position of the rod and the boring machine; 5 - Re-entry vehicle ampule; 6 - Soil; 7 - Cap lock; 8 - Ampule sealing cap; 9 - Ampule clamping spring; 10 - Body of drilling machine; 11 - Rotator; 12 - Lead screw; 13 - Drill.

glass is filled with lunar soil. The steel "arm" carefully raises this glass to the top of the moon-earth vehicle which is on the

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Fig. 20. The site on the moon's surface for collecting soil samples (the photograph was taken when the sun was at an altitude of 60° above the local lunar horizon). At the left of the photograph -- the whip antenna of the landing stage radio complex; at the right of the picture -- the drillhole left after the drilling machine had finished work; in the center -- the rod with the drilling equipment brought to one side after drilling.

"launch platform" of the landing stage. The precious minerals of the lunar highlands are placed in the vehicle which will return to earth approximately one day later.

The moon-earth vehicle is much smaller than the landing stage. /99 Its operation is simple and reliable. Once a day a moment arrives when the vehicle can reach the earth, having taken off directly vertically from the moon and having attained a speed of 2.7 km/sec. Such are the laws of space. The Luna-20 observed this launch moment and followed in the estimated course (Fig. 21).

Scientists are awaiting the arrival of soil from the highland region with great impatience. According to their calculations, the age of these minerals must date back to a far epoch of the solar system's formation. If this is so, many secrets of the origin and developments of planets can be discovered.

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Fig. 21. The Luna-20 station's re-entry vehicle on earth!

A Mirror of Earth

Professor Yu. Surkov

"Pravda", February 27, 1972.

For many years scientists have /101 been interested in the moon's composition. However, it was impossible to determine this by astronomical observations. Theories of lunar matter included practically all types of rock known on earth. The first valuable information on lunar matter, its formation and other properties came from the Luna-9 which made a soft lunar landing in 1966.

Soon afterwards the first satellite, the Soviet Luna-10 automatic station went into lunar orbit. It contained an instrument for determining the content of lunar soil and natural radioactive elements contained in it. It established for the first time that there is igneous rock, the composition of which is close to basalts which are widely found in the earth's crust. Several years later, scientific laboratories began studying lunar rock brought back to earth by Apollo spacecraft and the Luna-16. Although these samples caused no sensational surprises in laboratories, this research was the beginning of a new stage of lunar research.

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As is known, the first samples of lunar rock were from the maria regions. Here, the surface layer of lunar matter was dark-gray fine-grained loose rock with low density and strength -- so-called regolith. It is formed easily and builds a vertical wall, similar to sea sand, although it is absolutely dry.

In structure, regolith is a fine-grained crushed material, consisting of particles of several varieties. Its basic components are splinters of magnetic rock of an angular shape and a fresh surface, and slaggy particles of indeterminate shape with fused edges and vitrified pores. Some of them are of spheroidal formation and are congealed droplets of melted magnetic rock.

According to depth, the structure, composition and properties /102
of this rock slightly vary. The number of particles increases, the amount of melted (vitrified) particles is reduced, the density and strength are increased, the elemental and isotopic composition are slightly changed, as are some physical properties. All these changes are caused by different cosmogonic factors.

The density of the surface layer of this rock in its natural stratification, according to information transmitted by the Luna-13, is approximately 1 g/cm^3. But, obviously, with depth this increases. The bulk weight of this rock, brought back from the Mare Fecunditatis by the Luna-16, in laboratory conditions is approximately 1.2 g/cm^3, but after settling and ramming it becomes almost twice as compact and is hardly as dense as granite.

Scientists believe that the surface layer of the moon was formed as the result of the destruction of the moon's bedrock by

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several cosmogonic factors -- impacts from large and small meteorites, cosmic rays and solar wind, a high vacuum and sharp temperature gradients.

The lunar surface also contains pieces of compact crystal rock, obviously, ejected from nearby craters as the result of volcanic eruptions or the fall of large meteorites. Their number increases when one leaves the maria regions and approaches the highlands. Near the Fra Mauro crater, where the Apollo-14 landed, for example, there are blocks of stone as big as a bus. It is obvious that this is undestroyed crystal bedrock. Now this is also being studied. In composition, structure and properties this rock differs slightly in various regions of the moon's surface.

In chemical composition, moon rock is basically similar to igneous basalt rocks commonly found in the earth's crust. At the same time, different basalt rocks on earth differ more from each other than samples taken from various regions of the lunar surface. There is also a small difference in composition between the moon's crystal bedrock and the regolith which covers its surface. Rock from the Oceanus Procellarum, on an average, contains 2-3 times less titanium than samples from the Mare Serenitatis. Samples from the Mare Fecunditatis are more similar to rock from the Oceanus Procellarum and less similar to rocks from the Mare Serenitatis. But, the Mare Fecunditatis is much closer to the Mare Serenitatis. However, rock of all maria have a similar number of basic elements.

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As for the basic minerals making up lunar rock, they are plagioclase, pyrocene, ilmenite, anorthite and others. The most commonly found mineral of the lunar regolith is anorthite and after this, augite and ilmenite. All of this shows that moon rock is of a basalt type in the widest sense of that word.

Scientists have carefully studied other properties of matter brought back from the moon, including its reflecting power, luminescence by charged particles, X-ray and ultraviolet radiations. The magnetism of lunar soil has also been studied. Results of this research showed that lunar rock, possibly, solidified in a significantly stronger magnetic field. Measured on the moon's surface, it is now approximately 0.1% of what is observed on earth. The study of lunar samples shows that the moon's magnetic field 3.5 billion years ago was approximately 10% of the earth's present field, that is, was approximately 10,000 times stronger. The reason for this remains unclear.

Extremely important information was obtained from research into the isotopic composition of individual elements. The age of lunar rock was determined according to the ratio of several isotopes of potassium and argon, rubidium and strontium, uranium and lead, and for various regions was slightly different. The formation of rock (crystallization) in the Oceanus Procellarum, for example, occurred approximately 3.3 billion years ago, and in the Mare Serenitatis 3.7 billion years ago. The age of the oldest rock discovered on the moon is 4.6 billion years. Consequently, it can be estimated that the moon was formed at least no less than

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4.6 billion years ago. This shows that the moon, after its formation, underwent several periods of "local" fusion, mainly in the maria regions. Fusions may have been caused by volcanic activity or large meteorites. Although the age of the earth, determined by radio isotopes, is also approximately 4.6 billion years, no one on earth has found a rock sample which was crystallized more than 3.5 billion years ago. This is explained by the fact that the whole geological effort on earth was "obliterated" due to erosion caused by wind and water. In this way, the study of lunar rock gives us information of the "vanished" billions of years of the earth's history.

It appeared that an upper layer of matter several centimeters thick has lain on the moon's surface for at least no less than 10 million years, and a layer 1-2 m thick no less than 600 million years. In this way, one can see that this upper layer was formed extremely slowly. This is not so on earth. Due to intense tectonic activity and atmospheric phenomena its appearance is constantly and quite rapidly changing.

Rocks on the moon's open surface are also subjected to erosion and being continually destroyed. This erosion rate, determined by traces of cosmic particles in the matter, is approximately one millionth part of millimeter per year. How many million years must pass before spacecraft left on the moon are transformed into lunar dust!

In spite of the enormous achievements in lunar research, the main problems of its origin and evolution are by no means solved.

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Until now, rock has been investigated mainly from the surface of the lunar maria, which are smooth and of relatively uniform relief. What type of rock do lunar "continents" contain which occupy the larger part of the moon's surface? What lies a few meters below the surface? These and several other questions have remained unanswered.

Now, the first task is to study the lunar "continents". Knowing the type of rock from which they are formed will allow one to answer one of the main questions: does the moon have a compact, basalt crust like that of the earth, or did it only undergo partial fusion, and did the lava only come to the surface in the maria regions? If there is a positive answer to the second part of the question, we may conclude that the main part of the lunar surface must be primary undifferentiated matter, having a composition similar to stony meteorites.

Apparently, the moon, like the earth, during its initial existence, heated up due to the heat given off when natural radioactive elements decayed. Lunar matter was differentiated, and low-melting fractions rose to the surface. These cooled and formed the lunar crust. When the lava cooled, which was a rapid process, differentiation of matter also took place. It is possible that layers of heavy ferrotitanian oxides were formed on the bottom of lava lakes, and at a depth of several kilometers layers of different minerals of lesser density were formed. Would this not explain the unusual seismic properties of the moon, which, figuratively speaking, rings like a bell when stuck by foreign bodies?

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On the other hand, it is quite possible that this process is linked /104
with another phenomenon, the discovery on the moon of so-called mascons, that is, regions with increased gravitation, which force artificial lunar satellites to change orbit.

Information obtained recently is making scientists form the opinion that the moon was born inside the solar system and, apparently, developed in the same way as the planets. But the small size of the moon must have been reflected both in processes determining its internal structure, and in those taking place on the surface. As a result, the lunar surface was continually affected by different space factors which formed its appearance. It is scientifically and practically important that events which took place on the moon long ago left their traces on its surface. On earth there are hardly any traces left of distant geological history, since its whole surface was covered by a layer of sedimentary rock. This explains the interest as shown by modern science to the moon, a unique mirror in which are reflected events which took place on our planet billions of years ago. By reconstructing them, we can determine what is hidden below the earth's surface, and which natural wealth man will be using in the future.

When the Drill Was Opened ...

V. Smirnov, a "Pravda" special correspondent

"Pravda", February 28, 1972.

Lunar matter (Fig. 23) brought back to earth by the Luna-20 re-entry vehicle, is lying on a metal tray, visible through the

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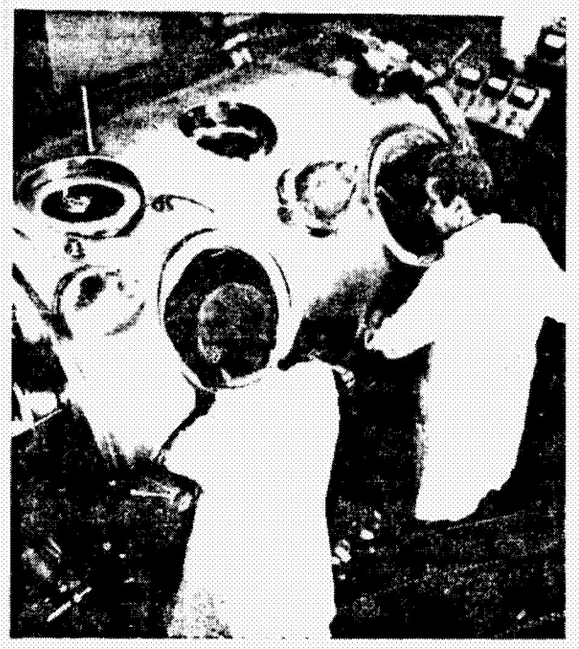

Fig. 22. The lunar soil chamber.

glass of the chamber's circular window (Fig. 22). Below is its used, darkened ribbed drill (Fig. 24). The chamber is filled with helium, a colorless, inert gas. At first air was pumped from it and later helium was pumped in, and only then was the pressurized container with lunar soil opened. But these simple operations took several hours.

Fig. 23. Lunar matter on a tray.

Almost exactly the same operations were performed on the "parcel" brought from the moon 18 months ago by the Luna-16. Then, as now, directly after opening the container we looked at its contents. It is true there are differences. Then, it will be remembered, there was a difference of opinion in the laboratory of the soil color. Some said it was brownish, others said reddish. This time we are all of one opinion, the substance is lighter than that which was brought back from the Mare Fecunditatis. It is gray,

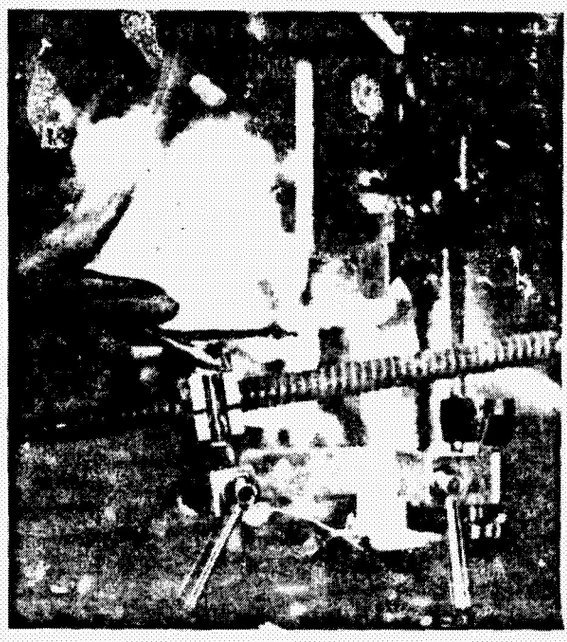

Fig. 24. The drill taken from the Luna-20 container.

like the ash of a burnt-out bonfire or cement scattered from a bag. Probably this is because it was taken not from the mare, but the highland region of the moon.

The tray is marked with centimeter and millimeter graduation lines. Against marks 29, 32 and 35 centimeters are larger whiter particles, 4-6 mm in diameter, in the general gray, fine-grained mass. There were none of these before.

However, all this is an outward impression. We understand that scientists will carry out careful study to answer the questions: what is the composition and properties of matter taken from the highland region of the moon?

A. P. Vinogradov tells us that these lunar soil samples, brought back by Luna-16, have been studied by scientists of many Soviet and foreign scientific institutions including Hungary, Czechoslovakia, France and the USA. We are mainly interested in the origin of this matter. We now have at our disposal various /105 methods and means for studying the physical and chemical and other properties of the matter. One only needs a particle weighing

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several hundred parts of a milligram to determine, for example, the absolute age of the rock to which it belonged. Methods for analyzing such a tiny grain will allow us to find chemical elements in it.

A. P. Vinogradov continued, as you saw, the soil now in the chamber is lighter. It contains lighter elements and larger particles than the matter brought back by Luna-16. From the rock placed on the tray one could also see that in the upper layer of the drill there were fine particles, and in the lower one, which had drilled deeper into the lunar surface, they were larger. There are also individual relatively large particles. I imagine that some of them could be anorthosite, one of the oldest rocks in the solar system.

The Luna-20 drilled for rock samples in the highland region near the Mare Fecunditatis, where the Luna-16 landed. Therefore, we assume that samples taken from neighboring regions of the moon differ geologically. Scientifically, this is very important. Research into these samples will give us an idea not only of an area, but of the whole geological province.

Automatic control units, bringing back rock samples from various regions on the moon, will enable us to determine the origin of the earth and planets, and their history. There are now two /106 theories on the moon's origin. One of them is that the moon is a "foreign" body which approached and, as it were, attached itself to earth. The other is that the moon broke away from its mother, the earth, and became its permanent atellite. But the moon has

an almost circular orbit. In either case this would not have been so. When it broke away from the earth or when it "attached itself to it, the moon's orbit would unavoidably have become elongated.

There is now a third theory: the earth and the moon were formed simultaneously and developed together side by side. Research into lunar soil brought back from different regions of the moon, undoubtedly, will help explain these questions, and this will have not only a scientific, but important practical value.

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"Pravda", March 2, 1972.

To scientists, designers, engineers, technicians, workers and all the teams and organizations who helped to create the Luna-20 automatic station which brought back to earth lunar soil samples.

Dear Comrades!

Another vivid page has been written in the history of space conquest.

On February 14, 1972 the Soviet Luna-20 was launched to the moon; it made a soft landing in the designated highland region of the moon between the Mare Fecunditatis and the Mare Crisium. The Luna-20 drilled and took samples of lunar soil, after which it was launched from the moon to earth. The re-entry vehicle with lunar soil samples was separated from it during the flight to earth. After aerodynamic braking, the vehicle landed in the specified area of the Soviet Union on February 25, 1972.

The laid down flight program of the Luna-20 has been completely /107
carried out. All the station's systems and ground facilities worked accurately and reliably. This is a new achievement for Soviet science and technology in moon and outer space research -- the result of the inspired work of the working class, scientists, designers, engineers and technicians of the Soviet Union preparing to meet the 50th anniversary of the formation of the USSR.

The Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR heartily congratulate all teams and organizations and all those who helped build the Luna-20 and achieve this flight.

May the creative spirit of the Soviet people prosper!

Long live the Communist Party of the Soviet Union which has inspired and organized our victories for our country's good and for the triumph of communism!

The Central Committee of the Communist Party of the Soviet Union.

The Presidium of the Supreme Soviet of the USSR.

The Council of Ministers of the USSR.

To the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR

"Pravda", March 2, 1972.

We, scientists, designers, engineers, technicians and workers who participated in the construction, launch and flight of the

Luna-20 report to the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR, that the complex scientific and technical problem of landing an automatic vehicle on the almost inaccessible highland region of the moon, the drilling for lunar soil and bringing samples of it back to the Soviet Union has been successfully solved.

During all the stages of flight of the Luna-20, from the earth to the moon, in selenocentric orbit, the soft landing on the planned area of the moon, the drilling and collection of lunar soil samples, the launch of the vehicle from the moon, its flight to earth and landing of the re-entry vehicle on earth, the station's equipment and systems, the command and measurement facilities and search groups operated accurately and reliably.

The flight program of the Luna 20 was successfully accomplished and once more demonstrated the great possibilities for automatic vehicles in researching outer space and obtaining scientific information from the moon's surface and planets of the solar system.

We assure the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR, the Soviet government and the entire Soviet nation that we shall devote all our efforts and skill to fulfill the party's and government's task of building new types of Soviet space equipment to research and develop outer space for the benefit of our people and the whole of mankind.

The Importance of Flights to Far Worlds

Scientific work in space and the continued research into the moon and planets of the solar system is one of the main tasks which the 24th Party Congress entrusted to Soviet science during /108 the present Five-Year Plan. Automatic space stations and equipment will play an important role.

The recent successful flight of the Soviet Luna-20 once more showed the great possibilities for using automatic vehicles and wrote a vivid page in the annals of world astronautics.

By systematically investigating the moon, Soviet scientists and designers used space vehicles for solving various problems: scientific research from near-moon orbit, the flight around the moon, taking photographs of its surface and bringing them back to earth, research of the moon in the landing area, and finally, bringing back lunar soil to earth.

Scientists of the Space Research Institute of the Academy of Sciences of the USSR tell of the way in which Luna and Zond flights have enriched science, and the new information which these space flights have provided on the enigmatic, extraterrestrial world.

The Moon from the Outside ...

Professor B. Rodionov

We know that the surface of planets are not exact spheres. Let us take the earth. It is slightly flattened and compressed towards the polar axis. This compression is the result of

rotation, and is linked with the viscosity of planetary matter, its structural layers, the structure of its nucleus and also its gravitational field. This is why determining planetary ellipsoids and compression plays an important role in cosmogony -- the science and nature of the universe.

Together with information on planets, obtained by analyzing their motion, and spectroscopic research into various radiation bands, information on planetary ellipsoids allows us, by comparison, to obtain some idea of the similarity or difference in internal planetary structure. This information is also important for compiling a system of geodetic coordinates which are the basis for cartography.

What has been said is also true of the moon. Photographs of the moon taken by automatic stations brought us nearer to solving this problem which, with the advent of self-propelled lunar robots, is becoming more important.

Lunar automatic control units have taken photographs not only of the central part of the lunar disc, but of its whole visible edge or, as astronomers say, the limb which is clearly seen on the background of outer space.

What has this meant to scientists?

Before automatic stations, we only had a concept of the moon's shape from observations of the hemisphere visible from earth. Naturally, this was not complete, since a considerable part of the moon could not be observed.

Scientists have different theories about the moon's shape. Some believe that it is almost a triaxial ellipsoid, the main axis of which is pointed towards earth. Others believe that the moon is shaped like a pear with the bulge in the southern hemisphere. In other words, it is geometrically asymmetric. In this case, planet matter would be distributed asymmetrically, and as a result, a mechanical system would have been developed which, in a freak state, would try to occupy a specific position towards the center of gravity, which is earth.

Apparently, photographs taken from space showed that those scientists were correct who believed that the moon was almost spherical. Consequently, the reason for the moon's unilateral orientation must be looked for not in its global geometric /109
asymmetry, but in its irregular distribution of masses of matter. Probably, these masses cause anomalies in the gravitational field.

The analysis of photographed limbs showed previously unknown formations. For example, an extensive depression was observed, arbitrarily called the South-Western Sea, in the southern part of the moon's hemisphere invisible from earth.

In our opinion, another discovery, no less impressive, are the four salient local protrusions on the limb profile near the area of the South Pole. The largest of these rises almost 8 km above the surrounding low-lying area.

Theories on the existence of such differences of altitude on the moon were expressed earlier by scientists based on indirect science. Now, this has been confirmed by direct measurement.

It is possible that this protrusion mentioned earlier is the highest point on the moon. If this is so, the honor for its discovery belongs to our lunar automatic control units.

One must have a network of points on the moon's surface, the position of which is known in the selenographic coordinate system, for compiling accurate maps, studying the gravitational field, navigating space vehicles and for other scientific and practical tasks. A network of this type was compiled from observations from earth on the moon's visible side. Naturally, they cannot include the far side of the moon. The first network of reference points was set up over the hemisphere not visible by using photographs transmitted by Soviet Luna-3, Zond-3 and Zond-6 space vehicles.

Photographic experiments from automatic space vehicles provide extensive material for studying the moon.

... and Inside

Professor K. Florenskiy
"Krasnaya Zvezda", March 3, 1972.

Successes in space research have shown that the moon has a complex geological structure: finely-crushed lunar soil, regolith, is a mixture, the basis of which is local crystal rock. At the same time, there is a certain amount of matter which is presumably connected with meteorites hitting the moon's surface.

As a result of determining the absolute age (crystallization time) of lunar rock, it was found that present-day maria are extremely old. According to information obtained by the Luna-16,

the depression of the Mare Fecunditatis was covered by lava more than 3.5 billion years ago. It is interesting that the absolute age of regolith, which covers this lava, is even greater.

It is known that the lunar surface is divided into two types of regions which must also differ in internal structure. The lunar highland regions are older than the lunar maria plains. The maria were formed by massive effusions of basalt lava which is the low-melting part of lunar matter and probably, could have been formed as the result of zonal fusion.

On earth there is a solid basalt envelope on whose surface light granite continents, as it were, "float". Many scientists believe that rock on earth underwent wind erosion and destruction by water and microorganisms to form granite. Only repeated recrystallization of sedimentary rock sinking into the earth can form granite. Incidentally, this problem is one of the most important in modern geology.

As yet, there is no direct information on the composition of /110
rock forming the lunary highlands. Some scientists believe they were formed similarly to those on earth, even if they are not true granites, but consist of anorthosite rock rich in feldspars.

Other researchers, pointing out the low radioactivity of lunar materials and their small size, believe that basalts are only typical of mare regions. In their opinion, highlands have a less differentiated primary matter and a simpler internal structure.

In any case, the highlands were formed at the beginning of the moon's existence. It is extremely important for scientists

to know how much rock can be isolated during the initial periods of a planet's existence when the main features of its structure are determined.

Basically, the moon is a solid heavenly body. It is highly improbable that it has a liquid core. Unlike the earth, there are no tectonic dislocations and large linear faults of the crust. There were no signs of water in samples brought back earlier from the moon. At the same time, volcanism must have been accompanied by the separation of water. This is one of many lunar paradoxes.

There is no doubt that the main chapter in the history of the moon will result from search into studying samples from the lunar highlands brought back by the Soviet Luna-20.

Discovering the Secrets of the Universe

B. Konovalov

"Izvestiya", March 4, 1972.

A Conversation with the Producers of the Luna-20

This conversation started in the coordinating computation center when it was learned that the re-entry vehicle had successfully landed and the tension was over. Leading specialists and producers of the Luna-20 drew up armchairs and were sitting around a small, low table. This conversation had the air of a "round table talk". Everyone said what he thought was most important and each complemented the other. The conversation was continued in the enterprise. I spoke to many people and the "collective answers",

if they can be called such, to questions which I asked are shown here.

The first question after important work has been completed, as always, is traditional:

Q: How do you rate the Luna-20 flight?

A: The whole flight was excellent. Instead of two regular, as we are used to saying, trajectory corrections during the moon flight, only one was required. The results of trajectory measurement showed that the vehicle was accurately sent into the area of near-lunar space where the engines were cut-in and deceleration was done to send it into selenocentric orbit. The forecast of the height above the lunar surface, based on ballistic calculations, had an error of only 1 km.

The landing on a small plateau-shaped area among the lunar hills, and the return to the calculated area of the Soviet Union was accomplished accurately, although no correction was planned on the return flight. The coordinates of the landing site, calculated according to ballistic prediction information, almost coincided with the actual ones. Of course, this made the search work easier, although this was done at night and during bad weather.

All the flight facilities operated accurately. We have no /111
complaints about the operation of individual station systems. It behaved magnificently both in flight and on the moon.

Q: However, were there times during the experiment when you were anxious?

A: Both landings, on the moon and on earth. A moon landing in the highland region is very complicated. Although, during the final stage, it is done automatically according to radio altimeter information, the overall station operation system is determined earlier. A lot depends on the work of the control group which makes the program of commands from earth more accurate.

During the return to earth, the stage which is completely automatic lasts longer. Therefore, there are probably more anxieties. Perhaps one already knows that the vehicle contains soil from lunar highlands, and it only remains to carry out final testing. Although this was another world when the craft landed on the moon and is now returning to earth, its task is not made easier. When the re-entry vehicle is separated from the rocket it is impossible to interfere with the on-board automatic equipment. It is impossible to help.

Q: To what extent did past flights help the success of the present one?

A: This is the 20th Luna vehicle. All of them, beginning from the first which was launched on January 2, 1959, have carried out their tasks, many of which were done for the first time in man's history. A satellite from earth took a pennant and made a soft landing on the moon. The far side of the moon was photographed for the first time and a picture was sent back by the vehicle which had landed there. Soil was investigated at the landing site and a satellite was sent into selenocentric orbit.

A self-propelled laboratory moved about on the moon for the first time, and rock samples from the lunar maria and highlands were sent back to earth by automatic means.

Technical successes are linked with scientific ones and depend on each other. We owe them to many teams and many people. Technical solutions and scientific research have progressed for the general good of mankind and the discovery of the universe.

Each stage of lunar discovery, in some way, resulted from another one. For example, the Lunokhod was built as the result of the Luna-9 and the Luna-13 which made soft landings and carried out direct research into lunar soil.

During the Luna-20 flight, experience was used which was obtained when launching its predecessor. For example, the Luna-19 is still researching the moon's gravitational field. As opposed to that on earth, it is non-uniform, and must be carefully studied when making moon landings, especially in highland regions. Over different regions of the moon there are "gravitational depressions", sharp changes in the gravitational field and these must be known and taken into account when making a soft landing. Of course, the main "base" of success of the Luna-20 and the Luna-16 was bringing back soil to earth.

Q: How do the Luna-20 and Luna-16 differ?

A: Their basic construction is the same. In essence, these are "systems". The Luna-20 is simply a technical improvement. By taking into account that it must make a moon landing in the highland region, we decreased the landing speed so that the landing of the

Luna-20 was the softest of all. Much new equipment give the vehicle increased reliability.

As opposed to the Luna-16, the Luna-20 landed on the moon in daytime and not at night. Telephotometers at the control point saw the surrounding area, chose a drilling site, and followed the /112
operation for placing the samples and sealing them in the re-entry vehicle. Apart from this, steroscopic photography of the area and obtaining panorama with the earth's image gave us additional information on the landing region.

Q: How did experience acquired when building the Luna vehicles affect design and engineering problems?

A: We have a well-developed system of unitization not only of individual assemblies and systems, but of whole automatic station units. Although they carry out different scientific tasks, where possible we try to use identical construction units. If one takes into account that for different problems not one station is built by several "twins" for tests, this method is extremely economical.

New generation automatic lunar stations use a unitized flight and landing stage. For example, this was used when the Luna-16 landed on the moon's surface and the Luna-17 set down the Lunokhod-1, and now the Luna-20 which brought back rock samples from the lunar highlands.

It is said that it is difficult to gain a victory, but more difficult to consolidate it. The producers of Luna-20 did this.

No doubt, they will successfully exploit their success in uncovering nature's secrets.

Future Lunar Automatic Control Units

V. Denisov, a Candidate of Technical Sciences
and V. Alimov, Engineer

"Sotsialisticheskaya industriya", March 22, 1972.

Approximately 60 vehicles have already been launched to the moon and are on the moon; of these, 85% were automatic and only a small percentage were manned.

Undoubtedly, automatic control units are required for flights into the scantily explored, almost inaccessible regions of space. The flights of Soviet automatic vehicles have shown their effectiveness in moon research. We are still thinking about the last achievement -- a precious "parcel" from the shores of the Mare Fecunditatis. As a result of these flights, our knowledge of the moon has been enriched with information which could not have been obtained in a century by direct observations from earth. One can say that lunar space research is one of man's most recent significant achievements.

Sending a payload to the moon is still a laborious process, however, there are a number of researches which it was better to conduct directly on its surface than creating a whole system of artificial earth satellites. For example, meteorological satellites are widely used for world weather forecasting. They collect information on the atmosphere over the whole world and processes

which are taking place in it. This information is a great help for meteorologists when evaluating the weather and, consequently, for forecasting it for a certain time. However, it is unrealistic to check the weather over large areas from one satellite. This observational disadvantage can be overcome by setting up suitable meteorological equipment on the moon.

The picture of air circulation in the atmosphere is extremely complex and defies analysis. Automatic meteorological stations on the moon, in the hemisphere visible from earth, will help to find laws for many processes, accurately forecast the movement of warm and cold air masses, and suggested changes in the weather.

Let us examine the second "profession" carried out by a lunar /113
automatic control unit. It is known that radio communication in ultrashort radio waves, used for television transmissions, is limited by direct visibility. The range for reliable reception of television signals depends on the height of the transmitting and receiving antennas. But the television broadcasting radius of the Ostaniko tower, one of the highest in the world, is no more than 130 km.

Artificial satellites and ground stations of the Orbita type significantly increase the "geography" of television. It will also be possible to place radio television equipment on the moon itself. In this case, programs transmitted from the planet will be received by lunar equipment, and then after amplification, transmitted back. Ground radio- and television receivers will pick up these transmissions and make them available for millions of people.

In the near future, the third "profession" of the lunar automatic control unit will be as follows. The earth's atmosphere hinders astronomers, astrophysicists and radio physicists who are studying surrounding space. The atmosphere, at first glance, is transparent, but in actual fact is an unsurmountable barrier for the majority of radiations coming from space. Only a luminous flux and a small spectrum of radio waves with a length of several millimeters to 30 m pass freely through it.

The remaining regions of the spectrum, including a vast range of radiations (with wavelengths of 0.01 millionth of a centimeter to hundreds of thousands of kilometers), are completely or partially absorbed by our atmosphere. It is known that primary cosmic rays, generated deep in the universe, "develop" when meeting the atmosphere and are converted into fluxes of secondary cosmic particles. Scientists, by indirect science alone, built up a primordial picture.

The air also prevents the penetration of some solar corona radiation. These and other regions of the electromagnetic spectrum not reaching earth carry valuable information on many questions of the universe linked with the appearance of stars and stellar systems and with the nature of our and other galaxies.

On the moon it is possible to research different radiations in their whole rich spectrum. Consequently, in the future, the moon will be a suitable base for astronomical instruments and even for setting up an automatic observatory. We shall be able to study cosmic rays, solar wind and corpuscular beams.

The resolving power of radio telescopes is very important when one studies distant corners of the universe, containing numerous stars and their clusters, pulsars, quasars and "neutron stars". It is characterized by the ratio of the radiation wavelength to the radio telescope diameter. The greater its diameter, the higher is its "vigilance" and the farther it can "see".

The size of radio telescopes can only be increased to a certain amount. Incidentally, this is almost impossible for existing ground means. Therefore, astronomers and astrophysicists are looking for possible "evasion maneuvers" on earth. Research into heavenly bodies is often done simultaneously by two radio telescopes at a considerable distance from each other. Radio signals synchronously recorded on magnetic tapes are received from the depth of the universe. Later, after processing, the recordings are compared and analyzed.

Practice and calculation have shown that the greater the distance between the radio telescopes, the more vigilant is the "duet". But there are limitations to this: the size of the earth /114 itself.

Radio telescopes on the moon can be coupled with those on earth, and the distance between them is now in the order of 400,000 km. As a result, the resolving power of a space telescope significantly increases, and it will determine more accurately the structure of small heavenly bodies which are far from the solar system.

One important factor of the moon must not be forgotten: there is no radio interference. This is very important when one receives weak radio signals from far space. On earth any electrical spark causes noise. Millions of industrial pieces of equipment constantly interfere with radio reception. Therefore, radio telescopes should be sited far from towns and industrial areas.

One must remember that the earth itself continuously radiates radio waves into space caused by thermal movement of charged particles. It is not surprising that sometimes a useful signal from distant heavenly bodies is simply "dissolved" in the chaos of all this noise.

Things are simpler on the moon. Equipment here can be completely screened from all terrestrial interference. It must be sited on the hemisphere not seen from earth. A lunar radio telescope has another advantage over one on earth. As is known, the moon rotates very slowly (in comparison with earth) around its axis. Hence, it is quite feasible to carry out longer continuous observations of a given area of the celestial sphere. Naturally, all the scientific information received will be transmitted by the radio telescope's special automatic equipment to an artificial lunar satellite, and afterwards relayed to earth.

We have only spoken of some "professions" of future lunar automatic control units. Doubtlessly, as science and technology develops, the number of tasks will increase significantly. Each new flight to the moon will increase our knowledge and bring back new information about the universe.

Lunar Highland Soil

A. Vinogradov, Academician

"Pravda", May 4, 1972

Whereas the Luna-16 researched the mare region of the moon (the northeast part of the Mare Fecunditatis), the Luna-20 brought back a soil sample from the typical highland region. Scientists believed they would find here surface rock with other characteristics. Therefore, the landing site of the Luna-20 was chosen 120 km directly north of that of Luna-16. The boundary of the mare and highland is approximately half way between these two points.

The Luna-20 landed in the area of the crater of Apollonius C, at a point with coordinates 3°32" north latitude and 56°33" east longitude, in the highland separating the Mare Crisium in the north from the Mare Fecunditatis in the south. There are no large young craters in the direct vicinity of the landing site. The terrain is hilly and broken, and there are some highlands with relative heights of up to 1 km. Geologically, this area is one of the oldest highland regions of the moon formed, probably, before the Mare Fecunditatis.

The sample brought back by Luna-16 is a hiatal dark, almost /115
black powder. Its component particles belong mainly to rock of the basalt type. The majority of particles bore obvious traces of partial melting, both glassy and vitreous from the surface, and many fused formations like congealed droplets of glassy and metallic appearance.

As a whole, soil brought back by the Luna-20 is incoherent hiatal material, but of a light gray color and much lighter than the sample from the Mare Fecunditatis. In comparison with soil brought back by Luna-16, there are considerably fewer fused particles, which in the sample from the Mare Fecunditatis had a strong "mirror effect". As with the Mare Fecunditatis, the soil from the highland region of the moon is capable of electrification. Its bulk weight, like the sample obtained by Luna-16, is 1.1-1.2 g/cm^3. They are easily compacted to 1.7-1.8 g/cm^3. According to granulometric analysis, the average size of particles is approximately 70-80 μm. There are more large particles, bigger than 1 mm, than in the sample brought back by Luna-16.

The lighter color of the soil was confirmed by albedo research (the reflection coefficient of light). The value of albedo was greater than in samples brought back by the Luna-16 and by the Apollo-11 and Apollo-12. For a fine fraction of regolith in ultraviolet it was 0.145, in the visible region -- 0.22, and in the near infrared -- 0.260. The maximum reflection is for a wavelength of 4 μm and equals 0.370 (in the case of Luna-16 in the same conditions was 0.280).

Microscopic study showed a sharp difference in the soil from samples taken from the Mare Fecunditatis. Here, there were many fragments of crystalline rock and minerals with well-preserved edges and chip surfaces; there were practically hardly any slag breccia and spheroids, characteristic of soil brought back by Luna-16. The overall mass of particles is anorthosite rock,

consisting, to a considerable degree, of feldspar (plagioclase). Among them were full crystalline, belonging to anorthosites, and particles of rock of the same composition, but of effusive appearance, that is, outwardly similar to volcanic rock on earth. Among these were individual grains of plagioclase which are seen in all granulometric types of soil. Apparently, the largest of these is crushed coarse-crystalline anorthosite. It is interesting that in anorthosite rock one constantly meets various sizes of metallic iron inclusion. It is important to note that there is rock consisting of plagioclase and olivine. As opposed to soil brought back by Luna-16, basalt type rock was normally represented by numerous particles of mare basalt, similar to that from the Mare Fecunditatis and other lunar maria. There was a certain number of particles of gabbro and peridot rock.

In this way, it appears that soil from the Mare Fecunditatis (as from other lunar maria) consists mainly of basalt type rock, and the sample from the highland region, brought back by Luna-20, consists mainly of anorthosite. In maria soil there was approximately 1-2% of anorthosite, and in highland soil approximately 50-60%. Among ferriferous minerals in a thin fraction of soil brought back by the Luna-20 there was 36% of olivine, 57% of pyroxene, and only approximately 1% of ilmenite, while in the maria sample from the Luna-16 of this titanium-bearing mineral there was 10% and in soil from the Mare Serenitatis (Apollo-11) more than 25%.

Finely atomized metallic iron, concentrated in the surface /116
layers, was observed in particles of lunar soil. There is an even

greater amount of it in the surface layer of soil particles brought back by Luna-20. This metallic iron does not oxidize in air. It was experimentally shown that iron, having the same properties, is sublimated in a vacuum from basalts heated to a high temperature.

In soil brought back by Luna-20 there were often pieces of metallic iron linked with silicates. This often consists of two polymorphic forms, typical of metallic iron of meteorites - kamacite and taenite rich in nickel. Apart from this, there is also metallic iron in particles of soil with a very small nickel content or completely without it. The question on the nature of this iron is still to be solved.

The soil was subjected to detailed physical and chemical research. It significantly differs in chemical content from maria soil brought back by Luna-16 and by the Apollo vehicles.

What is the first information we have on the content of the main components of the matter brought back by Luna-20? This is shown in the table.

Components	Crystalline rock		Soil (regolith)	
	Basalt -- Luna-16	Anorthosite type with olivine -- Luna-20	Luna-16	Luna-20
Silicon oxide	42.95	42.4	41.90	44.40
Aluminum oxide	13.88	20.2	15.33	22.90
Iron oxide	20.17	6.4	16.66	7.03
Calcium oxide	10.80	18.6	12.53	15.20
Magnesium oxide	6.05	12.0	8.78	9.70
Titanium oxide	5.50	0.38	3.36	0.56
Sodium oxide	0.23	0.40	0.34	0.55
Potassium oxide	0.16	0.52	0.10	0.10

The first thing one notices is the high content of aluminum oxide and especially calcium oxide in crystalline rock, and in soil (regolith) of the Luna-20 -- as the result of the high content of plagioclase (anorthite). Samples of regolith with such a high content of these oxides had previously not been obtained from the moon. The content of iron oxide is considerably less in highland regolith. There is only a small amount of titanium oxide in it, part of a percent, in comparison with mare soil. There are more alkalis in soil from the Luna-20, although the difference is small.

There is a characteristically high content of nickel and platinoids in hiatal highland and mare soils. This is a sign of meteorite matter striking the material. In this way, one can say that micrometeorites fell onto the moon's surface uniformly -- both on its visible and the highland side which we cannot see. The small amount of chromium is rather surprising.

Now, the content of more than 70 chemical elements in the soil brought back by Luna-20 can be determined by the mass-spectral method. This gives a rough idea of processes causing the formation of anorthosite in highland regions. From examples shown above, one can see that there is a considerable difference in the nature of surface rock of lunar mare and highland regions. As for mare regolith, it can be confirmed that it was formed from local crystalline basalt rock, the composition of which varies little in different maria. However, the problem of the origin of /117

mare regolith is still not solved. As for highland soil, its origin is a mystery.

The boundaries of the extent of different soils on the moon are quite clearly defined. For example, this can be seen by the boundary between the Mare Fecunditatis and its northern margin, where the Luna-20 took the sample. Strictly speaking, we know little of the origin of anorthosites. The discovery of this rock in the highland region of the moon revived old geological ideas of a primary anorthositic crust of the earth and, consequently, of the moon. It is known that anorthosites are seen on earth, especially in old Archaean and Proterozoic formations with an absolute geological age of up to 3-3.5 billion years. All anorthosites, including lunar ones, contain small amounts of so-called mafic elements -- iron, vanadium, manganese and titanium. As we saw, the high content of these elements is characteristic of mare lunar basalts, a large amount of aluminum and calcium has also been seen in anorthosites.

In the example of the extent of anorthosites in highland regions, the importance is seen for investigating the moon and planets to understand terrestrial processes, mainly during the early life period of our planet. The discovery of the method in which anorthosites were formed on the moon would make it easier to understand geological processes on earth. It can be said that the formation of anorthosites, apparently, takes place during the crystallization differentiation process of basic gabbro-basalt magma. Anorthosite is differentiated during the extremely rapid

discharge of magma in high temperatures and a high vacuum characteristic of the moon. It is true that one requires a certain amount of water in magma for this. However, there are signs that lunar magma had a high temperature and there were a few volatile compo nents in it, similar to water, gases and carbonic acid. On the other hand, one must take into account that it would be difficult for such volatile compounds to leave the moon for outer space. Briefly, the problem of the formation of anorthosites will be the focal point of attention.

The comprehensive study of samples brought back by Luna-20 continues. There is no doubt that scientists will discover new facts of great interest for cosmogony, geology, and geochemistry of the earth and other planets. The flight of the Luna-20 brought back material of extreme value.

A Window into the Moon's Depth

"Nedelya", No. 20, May 15-21, 1970.

Seismometers on the moon registered the fall of a meteorite with a diameter of approximately 3 m. There was an explosion and a 100 m (in diameter) crater was formed on the surface of the planet.

M. Lazarev, a correspondent of "Nedelya", contacted the head of the laboratory at the Space Research Institute at the Academy of Sciences of the USSR, K. P. Florenskiy, and asked for information.

"This is a remarkable event, especially since it took place under our very eyes. The fall of such a large meteorite is a

relatively rare occurrence. Not less than a million years will pass before the new crater begins to age. Until now, researchers into the moon's surface only dealt with existing craters. The study of a new formation will help uncover the history of old craters.

Simultaneously, several complex questions must be solved. In particular, why such a large meteorite formed a crater only 100 m across? The fact is that when a meteorite falls at normal speed (several tens of kilometers per second) the crater formed is /118 normally approximately 1,000 or, at least, 500 times greater than the size of the falling body. In other words, a 100 m crater can occur when a meteorite falls whose diameter is only 30-40 cm. The newcomer from space in question either fell slowly or there are other reasons.

When the meteorite struck the surface of the moon there was an explosion equal to 1,000 tons of TNT. If the real force of the blast wave had been recorded the new crater must be 20-25 m deep. This is another window into the moon. When the crater is seen on the surface, by studying the new profile, we shall obtain further information on the moon's upper layer. The first details of this were obtained by the Lunokhod-1. It found that the moon's upper layer is regolith and is from 2-5 m thick; below this is bedded rock. These new facts were subsequently confirmed by American researchers.

However, information can be obtained on the moon's general structure to a depth of tens and hundreds of kilometers by the

nature of earth wave propagation caused by the explosion. This, possibly, will be scientifically very important. The fact that this powerful explosion was registered by instruments on the moon is very valuable."

"Lunite" Is Being Made on Earth

B. Gerasimov (Our special correspondent)

"Sotsialisticheskaya industriya", October 13, 1972.

In one of the laboratories at the Space Research Institute of the Academy of Sciences of the USSR I witnessed a rare experiment. A transparent plate lightly covered by ordinary looking gray powder, was taken from a safe. It was placed under a microscope and I was invited to look at the powder more closely.

It was an unforgettable experience. As if some mysterious sculptor had worked with specks of dust and given each one a mysterious shape. Various globules, small dumbbells and "little cucumbers", flowing with all colors of the rainbow, and forming a remarkable, unearthly decorative pattern.

"You are not mistaken," laboratory workers explained to me. 'This mysterious powder is, indeed, of unearthly origin. Until recently it was on the moon's surface."

I am invited to a second microscope. The same plate, the same gray powder and the same shape of crystals. It appeared that there was another sample under the microscope which had been brought back from the moon.

"From the moon? You are wrong," and the person to whom I was talking smiled. "By the way, even an experienced jeweler would have difficulty in spotting the imitation."

Yes, this time there was a sample of "our" earth soil under the microscope. Do not rush to find it in the earth, this will be useless. The "lunite" is obtained artificially in laboratory conditions. Its similarity to natural ones in a chemical composition and physical and mechanical properties is amazing.

But why do we on earth need this "lunite", when we have real lunar soil at our disposal? This is not an easy question to answer -- the experiment program includes a wide range of problems.

Our conversation in the laboratory continues. M. D. Nusinov /119 and A. I. Kosolopov, candidates of science and senior scientific workers, name the basic stages of study of the moon and near-lunar space.

"Probably, each new lunar experiment poses more new questions than it gives answers. Everything becomes a subject of argument: when the moon was formed was it cold or, the reverse, extremely hot; was it "born" together with the earth or at a great distance from it -- at one of the crossroads of the solar system? Hundreds of "oddities" on the moon are disturbing space researchers more and more.

Synthesizing lunar soil in our laboratory, is only one of the scientific problems studied at the Space Research Institute. But what is interesting in that our experiment, probably, is one of the

few in which scientists are interested not in the final but in the initial result.

Judge for yourself. In order to obtain "lunite" in the laboratory, one must understand and simulate processes which took place in its "birth" in natural, lunar conditions. Here the criterion is the final product. It is similar to matter brought back from the moon, which means that scientists understand the process which created it. Is it not tempting to know what happened with the moon millions and billions of years ago? Furthermore, its plain regions are not only covered by a layer of regolith -- this is also seen, as the Luna-20 showed, in the highland region.

Indeed, when soil samples began arriving from the moon many previous hypotheses were destroyed. For example, that of Thomas Gold on "lunar dust" which would swallow up anyone who dared to land on the moon's surface.

What in fact does its surface look like? Covered by regolith, it maintains its same primordial form of a billion years ago and retains all the "scars" (meteorite impacts, etc.) which occurred when it was formed, and at a later stage of its space maturity. Much can be explained by this primordial picture, guaranteed by its very nature, which has no age-long elements which destroy its calm -- hurricanes and winds. The high vacuum here means there is no atmosphere and no atmospheric precipitation.

The regolith itself is a fairly loose material, consisting of dust, sand and particles of bedrock. Ingredients have also been found containing splinters of fallen meteorites. It also contains

various glassy and vitreous particles -- globules, "little cucumbers" and prisms with which we are familiar. These particles are the reason why, to man, the light side of the moon did not appear spherical but flat (the "cat's" eye effect).

The moon's secrets are being revealed gradually. But one of the main mysteries still unsolved is the origin of regolith. American researchers believe that regolith is formed by the impact of micrometeorites. These space newcomers crash into the moon's surface layer at great speed (up to 72 km/sec). The impacts are accompanied by microexplosions and these, in their turn, cause evaporation of the micrometeorite and partial evaporation of the soil itself. And so a new explosion crater appears on the moon's surface, around which molten particles were cooling a moment ago."

According to Soviet geochemists headed by Academician A. P. Vinogradov, not only space micrometeorites help to form regolith. One must also take into account so-called endogenous processes, mainly lunar volcanism.

Who is right? The only judge in this argument can be an /120
experiment making it possible to check various points of view.

The equipment used is justifiably called lunar. Impressive low-pressure chambers with all types of mechanisms, instruments and sensors. Here, man-made lunar processes take place, sometimes taking place in a millionth part of a second, but reaching a temperature of several thousand degrees, or as slowly as festive salutes illuminating the face of the moon.

The equipment can simulate much which happens on the moon's surface. Scientists use a laser beam for the effect of micrometeorites. The length of this can be varied widely -- to a millionth part of a second. The beam strikes the basalt target in a vacuum causing "primordial" evaporation and spattering of material. One already has the space particle's autograph -- through a microscope one can see the "lunar" crater which has just been formed.

I am invited to examine a simulated eruption of a lunar volcano, possibily, that which occurred billions of years ago. Through a solid illuminator I examine a crucible made of tempered, tungsten wire, called here a "little boat". It contains grains of earth basalt.

One can scarcely hear the withdrawal pumps and instruments calculating the last molecules of earth air in the chamber. There is now a space vacuum behind the glass. An electrical current passes through the crucible and the temperature in it rises to 1,200-1,800°. Since this takes place in a vacuum, the basalt yields much earlier than in normal conditions. It has already melted and is beginning to boil. The order for the eruption is given.

Gaseous helium is pumped through an aperture in the bottom of the "little boat". Its role is purely mechanical: the jet of gas hurls the boiling basalt upwards. This firey fountain is a miniature copy of an actual erupting volcano.

But what was waiting on the moon for a column of lava erupting from its depths? This has also been studied by researchers. In

the upper part of the chamber, the fountain of fire strikes the cold, glass plate, simulating space cold predominant on the moon's surface.

"Out of the frying pan into the fire" is the best way to describe these lunar metamorphoses. With such rapid cooling a basalt deposit is formed accompanied by glassy particles -- globules and dumbbells .... This new matter is dark gray in color, loose and easily adherent. It is almost a 100% twin of the natural regolith from lunar mare regions.

My interesting stay in the laboratory ends and M. D. Nusinov says, "As you see, experiments are bringing to life theories for the formation of lunar 'soil' suggested by our scientists."

Undoubtedly, future research will solve many problems of the moon's origin, that of the earth and, perhaps, of the whole solar system. For example, why not (knowing, of course, the initial information) simulate mysterious martian processes on earth?

Much useful work can be done by scientists in space simulation. But at the present it is impossible to judge the benefit of synthesized matter. Undoubtedly, "lunite", side by side with natural regolith, is a great help for those producing lunar equipment. As is known, this equipment is developed on earth.

Man's Space Hands

A. Mikhaylov, Academician

"Pravda", February 29, 1972.

When planning space research the question often arises: /121
automatic control unit or astronaut? The answer to this depends on the stage of research, on one hand, and the object of research, on the other. Undoubtedly, automatic control units first explored and worked in space. Near-lunar space was studied when the first artificial earth satellites were launched -- first in the USSR and afterwards in the USA. They obtained information on the dangers of radiation and meteorites. Man could only accomplish space flights later, and the first man in space was Yuri Gagarin, a citizen of the USSR.

Information on the structure and physical conditions on the moon, obtained from ground observatory observations, were supplemented by more detailed research using space rockets and automatic stations. Luna-3 and Zond-3 first photographed the far side of the moon. The American Ranger vehicles showed parts of the moon at close range and in great detail. The Soviet Luna-9 first made a soft landing on the moon and transmitted a picture of its surface with amazing detail, and supplied important information on the strength of lunar soil. This was of exceptional value since opinions on the nature of the soil were quite contradictory. In addition, these properties were investigated both by Soviet and American vehicles.

Artificial lunar satellites established the mass, gravitational and magnetic field, the reflectance and radiation characteristics of the lunar surface. Extremely detailed pictures of practically its whole surface were obtained which could not be determined from earth even with the largest astronomical instruments. Now, automatic control units are allowing scientists to carry out effective, comprehensive research in the most difficult conditions of outer space.

The Luna-16 made a soft landing on the moon in the northeast part of the Mare Fecunditatis, drilled the lunar soil to a depth of 35 cm and brought back to earth a column of regolith for laboratory research. In November 1970, the Luna-17 landed in the region of the Mare Imbrium, and the Lunokhod-1 self-propelled vehicle, equipped with various instruments, emerged from it. It was supplied mainly by solar batteries and, therefore, the active periods of the "moon research vehicle" were during lunar days. In 10.5 months, or 11 lunar days, the moon research vehicle traveled 10, 540 m, examined approximately 80,000 m^2 of lunar surface, transmitted more than 200 panoramas of the surrounding area and took more than 20,000 photographs. It studied the physical and mechanical properties of the soil and determined its chemical composition. The French angle reflector in the moon research vehicles was used for lunar laser location.

One extremely important fact must be mentioned: the equipment sent to the moon did not work independently. In other words, it did not only carry out a program fed into it earlier, which, by

necessity, would have had limitations, restricted its maneuverability and capability of operating independently of factors which occurred. The equipment continually worked in close communication with earth and followed out the ground center's instructions, which traced each movement of the research vehicle and the functioning of its equipment. For example, when the moon research vehicle met a steep crater or large stone, the operator on earth guided it around the obstruction. This was as if a person on earth had hands /122 which reached the moon and controlled instruments there.

The moon research vehicle successfully worked on the moon in a high vacuum, great temperature gradients, etc. An automatic control unit is more easily protected from the harmful effects of the surrounding medium, and the energy required for operating the equipment can be supplied by solar batteries. Briefly, it can carry out a wide selection of tasks.

In our first steps into space, knowledge is more important than perception, but in the future controlled automatic control units will probably transmit not only what the brain can accept, but can influence our five senses. A man, remaining on earth, but linked by electromagnetic waves with an automatic control unit in space or on another planet, will have the impression that he himself is in the place of the automatic control unit in completely unusual conditions. Of course, he will be in no danger whatsoever.

In this way, it is quite feasible to have an automatic observatory on the moon carrying out different astronomical, physical and geological observations and research controlled from earth and

transmitting information using radio and light. Undoubtedly, the organization and especially the use of this observatory will be much cheaper and less complex than a manned observatory on the moon. The present conditions and rate of development of science and technology will make this possible in the very near future.

What has been said is true of Venus, Mars and other planets. Great efforts and resources are required for an astronaut to remain active during the many months of flight to these planets. It is even more difficult to land there and work there, for example, on Venus with its extremely high temperatures and atmospheric pressure, or on other planets, the atmosphere of which contain poisonous gas. No, success here for a long time will be in the "hands" of automatic control units.

I believe that with the further development of automation and telemechanics, manned expeditions and flights to planets entail great risk and expense, and should be put into the background and only in an extreme case may be used during auxiliary but not main tasks. Of course, this does not apply to orbital stations which must be manned.

The accurate flight of the Soviet Luna-20 confirms the above. The Luna-20 brought back to earth new samples of lunar rock from the highland region. This considerably increases our knowledge of the mineralogy and geology of the moon, since, until now, we only had information from the so-called mare regions. It is difficult to overestimate the scientific value of the new

achievement of space automatic control units allowing Soviet science to make one more important step in studying bodies of the solar system.

IV. RESEARCH INTO DISTANT PLANETS

A. RESEARCH INTO VENUS

A New Success of Soviet Astronautics

"Pravda", August 17, 1972.

A vivid new page has been written in the annals of Soviet and /123
world astronautics. The Venera-8 automatic interplanetary station reached Venus after four months of flight, and its descent vehicle made a smooth descent in the atmosphere on the illuminated side of the "Morning Star", and made a soft landing on its surface. Valuable scientific information of the unknown properties of the atmosphere on the diurnal side of Venus, and the nature of rock on its surface layer was transmitted back to earth for 50 min.

The Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR heartily congratulated scientists, designers, engineers, technicians, workers and all teams and organizations participating in producing, launching and controlling the flight and landing the Venera-8 automatic interplanetary station. "This outstanding achievement of Soviet Science and technology was made possible due to the inspired work of the Soviet nation, greeting the 50th anniversary of the formation of the USSR with new feats of labor."

This remarkable scientific experiment is another clear demonstration of the possibilities of automatic vehicles for researching outer space and planets of the solar system. The Venera-8 successfully carried on the work of other automatic vehicles giving much important information on the universe and consolidating the USSR as the true authority on initial space flight.

Scarcely 15 years have passed since the whole world was astounded by the call signs of the first Soviet artificial earth satellite. The "beep-beep-beep" signal was of the man-made device, arrived from orbit and showed the genius, technical skill and economic might of the USSR. Since then, mankind has passed through real "space" universities".

There have been outstanding manned flights beyond the earth, the first of which was that by Yu. A. Gagarin. Man has been into open space and landed on the moon. The Salyut manned orbital station has been produced -- the forerunner of space laboratories of the future for prolonged research of the earth and interplanetary space.

Space automatic control units have served science well in this field. They showed their worth in near-space and continued far from our planet. Twenty-five Soviet "lunar probes" have given valuable information. Progressive, international public opinion has recognized the importance of the work of the Lunokhod-1 self- /124
propelled vehicle over many months, and has recognized it as the prototype of planetary research vehicles of the future; flights from earth-moon-earth by the Luna-16 and Luna-20 which brought

back lunar rock samples. The crowning achievement was the flight of Soviet Mars-2 and Mars-3 stations which became artificial satellites of the "red" planet, sent down an instrument capsule to its surface, and discovered much new information about Mars.

Soviet automatic control units gave much important information towards our knowledge of Venus. They are determining the level of our scientific concepts of the mysterious "Morning Star". Soviet Venera stations consequently solved a number of complex scientific and technical problems: one of the stations reached the planet for the first time; others descended smoothly in its atmosphere and gave us valuable information of its composition. Now there is a new remarkable success: the vehicle, notwithstanding the intense heat and high pressure, "sensed" Venus itself, measured its illumination for the first time and other characteristics of the diurnal side of the planet. The earth clearly heard the station's voice transmitting unique information from a distance of tens of millions of kilometers, the huge radio bridge operated perfectly. The accuracy of ballistic calculation was remarkable: it was calculated that the space "snipers" had hit a target as bit as a ten kopek coin moving at a range of 80 m.

One sometimes hears it said that the triumphs of astronautics have ceased to amaze people. Perhaps the opposite is true: astronautics has amazed and continued to amaze the human intellect, and the daring and limitlessness of human resources. The Soviet nation is indeed proud that it was the first to bring about these

achievements and throughout the whole space age leads the conquest of space for friendly purposes.

Ahead are new launches into space. They will provide knowledge of our planet and space, develop science and technology and solve various national economic problems. This was determined by the Directives of the 24th Congress of the Communist Party of the Soviet Union, which envisage the implementation of scientific work in space to develop long-range telephone and telegraph communication, television, weather forecasting and the study of natural resources, geographic research and solving other national economic problems by using satellites, automatic and manned vehicles, and also continuing research into the moon and planets.

In setting such wide tasks, the party and government will focus its attention to the development of the whole of Soviet science, including one of the main directions of scientific and technical progress -- astronautics. The Soviet nation thinks highly of the achievements of all those who took part in preparing and conducting space experiments, will create conditions for fruitful work, and heartily wish that new successes will be achieved in conquering space. To these wishes may we add those of our friends of other socialist countries, and people of good will throughout the whole world. They clearly see in these achievements the creative power of socialism.

The enormous success in research of Venus is an important page in the report on the feats of labor in honor of the 50th anniversary of the formation of the USSR. In the future, may this book of

national achievements, both on earth and in space, of the builders of communism be filled with important entries!

A TASS Report: The Venera-8 on Route

"Pravda", March 28, 1972.

In accordance with a research program of outer space and planets of the solar system, on March 27, 1972 at 7 hours 15 minutes Moscow time, the Venera-8 automatic station was launched in the Soviet Union. /125

The main aim of this new space experiment is the continuation of research into the planet Venus using automatic stations. Scientific equipment in the Venera-8 will obtain additional information about the planet. During the flight from earth to Venus it is planned to conduct research from the station on the physical characteristics of interplanetary space, especially measurement of the concentration of neutral hydrogen and solar plasma fluxes.

The Venera-8 contains pennants with the bas-relief of Vladimir Il'ich Lenin and a picture of the State Emblem of the USSR.

The weight of the station is 1,180 kg. It was launched towards Venus from intermediate artificial earth satellite orbit at 8 hours 45 minutes Moscow time. The engines of the final stage of the launch vehicle functioned for 243 sec and gave the station a speed of 11.5 km/sec -- slightly greater than the escape velocity. According to ballistic measurement, the trajectory parameters are close to the calculated ones.

In July 1972, after flying 312 million kilometers, the Venera-8 should reach the vicinity of the planet.

According to the program, the descent vehicle should separate from the station and descend smoothly in the atmosphere of Venus and carry out scientific measurement.

According to telemetering information, the on-board systems of the Venera-8 automatic interplanetary station are working normally. Radio communication with the station and receipt of scientific information will be carried out on a frequency of 928.4 megahertz. At 12 hours Moscow time on March 27, 1972, the station was at a distance of 65,000 km from earth above a point on the earth's surface with coordinates: 0°33" north latitude, 78°25" east longitude.

The flight of the Venera-8 is being controlled from the long-range space communication center. The coordinating computation center is processing the incoming information.

The Amazing World of Venus

M. Marov, Doctor of Physical and Mathematical Sciences

"Izvestiya", March 28, 1972.

We are living through an exciting time, when science is "fiercely" attacking" planets near earth. Space vehicles, containing daring, scientific projects and the latest achievements of engineering, have brought us nearer to our objects of research which are at a distance of tens and hundreds and millions of

kilometers. The Mars-2 and Mars-3 have been "reporting" from near-Mars orbit. Now, a new Soviet Venera-8 automatic station has been launched on its long journey. It will continue research successfully begin by its predecessors.

Over the past ten years, so fruitful for studying those regions of outer space and the heavenly bodies close to earth, scientists began to realize that Venus is a significantly special, wonderful /126 world, full of mystery and surprises.

Imagine the conditions on Venus from the viewpoint of an observer on its surface. What would he see and transmit to earth? There is no question that the fantastic nature of such a situation is not only linked with the complexity of the flight, but the unusual harsh climate on Venus. Measurements made by the Venera-4, -5, -6 and -7 showed that Venus is surrounded by a powerful, hot carbon dioxide atmosphere. Its surface temperature on the night side where the Venera-7 landed is approximately 500° C (almost the temperature of red heat!), the pressure is approximately 100 atmospheres -- almost 100 times greater than that on earth, or that of the ocean at a depth of 1 km. The density of the atmosphere is 60 times greater than that of air on the earth's surface. This creates many features of interest to an observer.

In daytime, he would hardly see the sun or the stars at night -- Venus is surrounded by thick dense clouds which, during the centuries, have hidden the planet from astronomers. It is true, the clouds are transparent for radio waves in the centimeter band.

Therefore, these features of Venus's own radiation have been carefully studied by radio astronomers. However, they could not confirm confidently that they could "see" the surface, and, consequently, determine the conditions on the planet.

The cloud and dense atmosphere greatly attenuate solar light. Therefore, it can be expected that the illumination on the surface of Venus is small. Most probably, it corresponds to our twilight on a dull day. There is little visibility -- the strong light scattering by molecules of such a dense gas must produce conditions close to those on earth during fog. However, if the visibility conditions in the atmosphere of Venus were favorable, the observer on its surface would see the astonishing optical effects due to the very strong refraction of light beams in the atmosphere. The horizon in all directions would appear elevated, and one would have the sensation of being on the bottom of a giant bowl.

The discovery of the planet's dense carbon dioxide atmosphere, and measurement of its parameters have made it possible to look for physical and geochemical mechanisms which cause these features, mainly its distinctive thermal conditions. These mechanisms must be directly linked with the interaction of the lithosphere with the atmosphere, the nature of the clouds and the planet's evolution.

Why did these high temperatures and pressure occur and remain on Venus? Apparently, the main reason is that Venus is approximately one third closer to the Sun than is the earth. Among suggested theories, the most worthy of mention are the so-called greenhouse model and the deep circulation model. The greenhouse

effect is well-known. For example, it is widely used on earth in hothouses: the glass frames let in sunlight which heats the soil, and the same frames prevent warmth from leaving. On Venus, the atmosphere provides the "frames". The creation of the greenhouse effect is significantly greater than in the earth's atmosphere.

Calculations show that even if a small amount of solar radiation reaches the surface, the carbon dioxide, with a very small admixture of water vapor (also observed in the atmosphere by direct measurement from the Venera stations), should hold back the outgoing thermal radiation. As the temperature and pressure rise, this effect is increased. Apparently, existing conditions on the planet are the result of gradual self-heating and now have some equilibrium state. Obviously, this balance is not only a temperature one, but a geochemical one, corresponding to the measured content of carbon dioxide and atmospheric pressure. As opposed to the earth with a moderate temperature, where approximately the same amount of carbon dioxide as in the atmosphere in Venus was linked in carbonates of sedimentary rock, on Venus, which is hot, the carbon monoxide moved from the lithosphere to the atmosphere and created the high pressure of the planet's gaseous envelope. /127

Another mechanism of heat exchange -- the deep circulation model -- stems from the assumption that solar rays do not reach the surface, and are completely held back by the atmosphere and clouds. In this case, the warming-up of the underlying atmosphere could occur as the result of the adiabatic compression of gas when it

is released into the lower layers of the atmosphere. The fact that the high-altitude temperature profile is close to the adiabatic one down to the surface, was observed as a result of measurement by the Venera stations. However, this fact is confined to concepts of the greenhouse model. Therefore, in order to choose between the two models, one must know how the attenuation of sunlight takes place below the cloud level which is visible from earth. Of course, one must allow for the possibility that the internal heat of the planet plays a certain role in its thermal conditions.

In both models one must assume the important role of circulation on Venus which evens the temperature between the day and night sides, and the equators and poles. This is indicated by radio astronomical measurement showing the absence of noticeable temperature changes of the surface and the lower atmosphere along the planet's disc, depending both on the phase and on calculations.

A most interesting problem is the nature of clouds on Venus. Solar radiation is strongly reflected from the upper boundary of the cloud layer visible from earth. This makes Venus such a bright "star" in the heavens, and only the Sun and moon are brighter. In essence, the problem of clouds on Venus has many forms, and until now only guesses have been made of their formation, composition and extent. It would appear that the most attractive hypothesis is that of water-ice clouds, similar to those on earth. This meets with certain difficulties. However, it is interesting to note that as opposed to the earth, where the clouds rarely rise above

10-12 km, on Venus similar clouds must begin at altitudes of almost 60 km, and their thickness (if one assumes the measured concentration of water vapor) must exceed 10 km.

Serious attention is being paid to other possibilities -- the abundance of dust in the atmosphere, and also the stratified cloud formation on Venus. The latter is a unique feature of this planet, and is a direct result of specific conditions existing there. The temperature on its surface is higher than the fusing or boiling temperatures of many elements and compounds existing in our natural conditions in the solid phase.

For example, apart from water, sulfur, bromine, iodine and mercury could have entered the atmosphere of Venus, and alkaline metals, tin and lead could be found on the surface in liquid form. But with altitude the temperature falls, and the vapors of impurities in the atmosphere must be condensated at different levels, similar to that which occurs when the temperature is reduced with water vapor. Therefore, there is the possibility of an extremely curious picture of a stratified cloud formation on Venus with an extremely unusual chemical composition of condensates of individual layers.

During observation from earth in ultraviolet rays, one can detect individual contrast details, not discernible in the visible region of the spectrum, in the structure of clouds of Venus. It was found that the displacement of these details along the planet's /128
disc, called "ultraviolet clouds", takes place approximately 60 times faster than the proper rotation of the planet itself.

On earth, the leading rotation of the atmosphere, no more than 1.2-1.4 times greater, is only found at relatively high altitudes -- 150-400 km. The nature of this interesting phenomenon is still not clear. On Venus, it is mainly linked with features of heat exchange and planetary circulation at the level of the cloud layer.

Measurements made by the Venera stations put an end to many years of argument on the predominant chemical composition and atmospheric parameters of the planet, and at the same time posed scientists a number of extremely complex questions. In particular, it is not clear why there is so little water. It would appear that in the planet's evolution process water would have been precipitated from below due to volcanic activity, as took place on earth. However, the water content in the atmosphere of Venus (of course, this is impossible on the surface in the liquid phase) is at least 1,000 times less than on earth.

One of the possible explanations is that the temperature of the cold region itself in the upper atmosphere of Venus (in the mesopause) is 10-20° higher, and sufficiently hard ultraviolet radiation can penetrate deeper than on earth. The result would be a more intense separation (photodissociation) of water into oxygen and hydrogen and an intenser "runaway" of light hydrogen from the atmosphere into outer space. The oxygen would not bond with the solid matter of the planet's surface.

The hydrogen corona of Venus was actually detected by measurement from space vehicles. However, this is small (the earth also has a hydrogen corona), and in order to judge definitely on the

possibility of its interest, in particular, one must know the ratio of hydrogen with its heavier isotope deuterium in the upper atmosphere of Venus.

This short list shown by no means exhausts the problems of Venus which exist, in spite of the enormous success achieved in studying it, and its title of "planet of riddles" is justified.

Venus and Mars are close planets, and they are interesting since scientists not only hope to find here the explanation for many astonishing natural phenomena, but also "read" the pages of history of the origin and development of the solar system, which have been erased over billions of years on earth.

Of course, to answer these questions one requires years of intense work, many complex experiments from space vehicles and intensive ground observations. This new flight of the Venera-8 automatic station will bring us closer to solving these interesting and complex problems.

A TASS Report: Venera-8 on Venus!

"Pravda", July 23, 1972.

Soviet science and technology have achieved new successes in the research of planets of the solar system.

On July 22, 1972, the Venera-8 automatic interplanetary station, having covered in 117 days a flight distance of more than 300 million kilometers, reached the vicinity of Venus.

When it entered the planet's atmosphere, the descent vehicle containing scientific equipment was separated from the station.

After aerodynamic braking, the descent vehicle made a smooth descent /129 by parachute, and at 12 hours 29 minutes Moscow time on July 22 made a soft landing on the surface of Venus.

This was the first landing of a space vehicle on the planet's illuminated side. A bas-relief of the founder of the USSR, Vladimir Il'ich Lenin and a picture of the State Emblem of the USSR was set down on the planet.

During the vehicle's parachute descent and 50 min after landing, scientific equipment carried out research into the atmosphere and the planet's surface layer at the landing site. This information was sent back to earth.

During the interplanetary flight 86 communication sessions were held with the Venera-8, during which the station was controlled and the on-board systems were checked, the trajectory parameters were measured, and scientific research was made into the physical processes taking place in outer space.

According to telemetering information during the flight, the station's systems and scientific equipment worked perfectly. A station trajectory correction was made on April 6, 1972 to bring the station towards Venus at the estimated time and land the descent vehicle in the appointed area. Trajectory measurement made later showed that the maneuver was done very accurately, and as a result, a second flight correction program was canceled.

During the flight in near-planetary outer space and the upper atmosphere of Venus, measurements of the radiation level, and the density of hydrogen and deuterium were made.

The descent vehicle was separated from Venera-8 at 10 hours 40 minutes Moscow time.

During aerodynamic braking in the planet's atmosphere, accompanied by a sharp increase of g-force and a considerable rise of temperature on the vehicle's exterior surface, its speed was reduced from 11.6 km/sec to 250 m/sec, after which the parachute system came into operation.

During the parachute descent the first research into Venus was done and experiments were carried out to determine the illumination, pressure and temperature in the atmosphere and on the planet's surface on its day side.

Information was obtained on the nature of rock of the planet's surface layer.

The results of scientific measurement are being processed.

The Soviet research program for outer space, the moon and planets of the solar system is being successfully carried out by automatic space vehicles.

This new success of Soviet astronautics, achieved on the eve of the 50th anniversary of the formation of the USSR, is remarkable proof of scientific and technical progress and the creative enthusiasm of all nations of the Soviet State.

The Earth and Venus -- Dissimilar Sisters

Professor V. Moro., Doctor of
Physical and Mathematical Sciences

"Izvestiya", July 25, 1972.

The study of Venus by descent vehicles is one of the most important directions in Soviet space research. The Venera-8 is the fifth space vehicle to have successfully descended into the atmosphere of this mysterious planet and transmitted new information about it, obtained by direct measurement. The USA plans the first experiment of this kind for 1975. /130

What do we know of Venus today and what would we like to know in the future? Venus, like the earth, moves in an approximately circular orbit. Its average distance from the Sun is 108 million kilometers; it is 1.4 times closer to it than earth, and receives approximately twice as much energy from it on one unit of area. However, Venus is a better reflector of solar radiation than earth. The majority of radiation arriving at the boundary of its atmosphere returns to space, and as a result approximately the same amount of solar energy heats both planets.

Apart from which, Venus and the earth are almost identical in size and mass, and have the same average density and acceleration of gravity on the surface. These two planets are real sisters. But it appears that these sisters are not similar to each other. According to measurements made by the Venera-8 on the surface, the temperature is 475-500° C. The atmosphere consists almost entirely of a great amount of carbon dioxide: the pressure on the planet's

surface is 90-100 atmospheres. One other feature is the small amount of water compared with the earth. What would happen to oceans on earth if our planet was heated to such a temperature? They would evaporate; the pressure of water vapor would be approximately 300 atmospheres, and the water vapor would become the main component of the atmosphere.

In essence, Venus is waterless. The relative content of water vapor was estimated spectroscopically by ground optical telescopes and by radio astronomical methods, and finally, was measured directly in the planet's atmosphere by the Venera-4, -5 and -6. According to this information, the relative content of water vapor in the atmosphere of Venus does not exceed 1%.

According to present-day theories, planets were formed as the result of the cohesion of solid particles in a cold proto-planetary cloud which surrounded the Sun during its formation. The earth could only maintain its original atmosphere, similar in composition to that of the Sun (hydrogen, helium, inert gases, especially neon) for a short time. Then, the initial atmosphere was almost completely lost (with the exception of heavy inert gases), and was replaced by a secondary one consisting of the products of volcanic activity.

Water was the main one of these products. There was 10 times less carbon monoxide and 300 times less nitrogen. Molecular oxygen appeared relatively later when vegetation appeared on the earth -- this gas was specifically terrestrial. Had there been no life on earth, there would have been hardly any of this gas. The

biosphere was also important since it extracted from the atmosphere the majority of carbon dioxide which formed sedimentary rock such as limestone. With the arrival of water, of which there was an abundance on earth, non-biological processes also took place which bound up carbon dioxide in rock (converting silicates into carbonates).

The similarity between earth and Venus in size and mass indicates the similar internal structure of both planets. Therefore, one could expect that almost identical volcanic processes took place in both of them.

In some aspects there is a real similarity: for example, the amount of carbon dioxide precipitated into the atmosphere of both planets during their evolution is almost identical. However, on earth it did not remain in the atmosphere, but became bound up quite rapidly in sedimentary rock. There is a great difference in the amount of water vapor.

Why did this occur? This is one of the main riddles. There are two basic theories. The first is that Venus was immediately formed "without water" since there were no ice particles in this part of the initial protoplanetary cloud owing to its proximity to the Sun (and higher temperature). The second theory is that the Venusian lithosphere produced the same amount of water as earth, but almost all the water molecules were destroyed by solar ultraviolet radiation and converted into hydrogen and oxygen. Later, hydrogen went into interplanetary space, and oxygen reacted with other gases. 231

The choice between these theories must be made in the future. One of the possible means of selection is to determine the relative content of deuterium and hydrogen in the water vapor and other hydrogenous gases of which there are small amounts in the atmosphere of Venus. The research done by Venera-8 into the density of deuterium and hydrogen in the upper atmosphere is very important. Atoms of deuterium are heavy, therefore, they leave the planet's atmosphere slower than atoms of hydrogen, especially if there is water and a large amount of carbon dioxide in the atmosphere.

Of course, there is no life on Venus in such severe climatic conditions. It is quite possible that the absence of water, the large amount of free carbon dioxide in the atmosphere, the high temperature, and the absence of a biosphere are mutually related phenomena whereby the lack of water is the main factor determining the remainder. A biosphere could not be formed without water and processes linked with carbon dioxide could not effectively take place. Accumulation took place and an atmospheric protection was formed which increased the temperature, and the atmosphere gradually acquired its present characteristics. It is possible that if the earth was deprived of water in the same way as Venus, the same thing would occur.

We have only mentioned one of the problems of research into Venus which are worrying scientists -- the problem of the evolution of its atmosphere. This is not the only mystery. We do not completely understand the physical mechanism which heats up its surface, although it is clear that it is linked with the opacity of

its atmosphere in the infrared region of the spectrum. The composition and formation of the planet's cloud layer has not been determined, neither has its role in the heating up of the atmosphere. However, one can be assured that there will soon be answers to these questions.

I would like to stress that the problem of evolution of planetary atmospheres is not an abstract one. Even a small change in the atmospheric composition and climate on earth is extremely dangerous, and therefore, it is important to understand how the composition of planetary atmosphere took place, and how the climate is determined by evolution factors. Detailed study of other planets of the solar system can give a clue to solving this problem so important for all mankind.

Towards Venus for the Sake of Earth

Professor A. Monin, the Director of the Institute of Oceanology of the Academy of Sciences of the USSR,
S. Zilitinkevich, Doctor of Physical and Mathematical Sciences

"Izvestiya", July 27, 1972.

The discovery of the planet Pluto by mathematical calculation became a textbook example of scientific foresight. However, methods and instruments at the disposal of scientists today allow greater and more complex problems to be solved.

Only recently, due to the work of radio astronomers and flights of automatic stations, has information been obtained on the properties of the atmosphere of Venus and the planet's rotation. However,

until now we had no experimental information on the winds blowing there. The information accumulated has already allowed the problem to be set on the theoretical calculation of the wind system and /132
temperature distribution, that is, the general circulation of the planet's atmosphere. Calculations of the "weather" of Venus were carried out during 1969-1972 at the Institute of Oceanology of the Academy of Sciences of the USSR.

Let me explain that this is a numerical experiment. At first, it was accepted that there was no wind in the atmosphere of Venus, the temperature on the surface was identical and dropped in altitude according to the so-called adiabatic law (which corresponds to complete agitation). Later, the solar source of heat was "included" and changes in atmospheric conditions were calculated with the passing of time. In this way, the numerical experiment reproduced the imagined behavior of the atmosphere as it would be if the temperature was evened out and circulation was "stopped"; we gave it, as it were, the chance to begin to develop again. There were reasons to suppose that after a more or less prolonged period of adaption, the model of the atmosphere would assume dynamic equilibrium with ambient conditions.

Calculations showed that equilibrium is attained after approximately one earth month, and as a result of the whole experiment, information was obtained on changes, over time, of the speed and direction of the wind, the temperature, atmospheric pressure, the vertical movement of gas, heat fluxes, and gas friction on the

surface during the whole Venusian diurnal cycle -- approximately 117 earth days.

Results of the experiment showed that the circulation of the atmosphere of Venus is practically symmetrical relative to the equator, and develops as a result of the temperature differences between the day and night hemispheres. These differences are constantly maintained since the day side of the planet is warmed by the Sun, and the night side cooled from above by natural radiation.

The circulation is not symmetrical relative to the axis of rotation nor relative to the line from the Sun to Venus: the region of greatest heating is close to the evening terminator, and the coldest area is near the morning terminator (a terminator -- is the line dividing the day and night hemispheres). The temperature differences in various parts of the planet are very small -- only 1-2°.

The wind system is as follows: in the lower layers, gases forming the Venusian atmosphere, converge towards the most heated region, and there rise upwards and spread in the upper layers, forming the "cold" region, and again descend. This movement spreads over the whole planet; there are no large-scale vortices such as cyclones and anticyclones. The standard wind speed is a little over 5-6 m/sec. For comparison, a typical wind speed on earth is almost 10 m/sec, but on Venus the density of the atmosphere is 10 times greater and normal wind pressures are 10-15 times greater than on earth, -- they correspond to our hurricanes.

Friction on the surface of Venus is 10-15 times greater than on earth. Therefore, one can expect that the planet has a smooth relief. It is interesting that, according to calculations, vertical speeds reach several centimeters per second (on earth they are measured in several millimeters per second). The whole lower atmosphere of Venus (troposphere) is in a state of convective mixing: on the day side this is caused by the heating from below, on the night side by cooling from above due to natural radiation.

Of course, all this information must be made more precise. The mathematical model needs to be improved, and one must introduce into it a detailed description of the vertical structure, and allow for new information, based on calculations of the observed properties of the Venusian atmosphere. We hope that new information transmitted to earth by the Venera-8 will provide material for making more precise the initial parameters of the calculation and for /133 comparing theoretical results with actual ones.

This article on the circulation of the Venusian atmosphere could end here. However, the reader has a right to ask: Why is this research necessary; why do we need to know about the circulation on another planet; and what practical use can be gained from this knowledge? These questions deserve a detailed answer. We shall limit ourselves to showing a few conceptions from the point of view of geophysics, a science which studies our planet. One of the most important tasks of geophysics is to learn to forecast theoretically what the "dynamic equilibrium conditions" will become

on our planet (a term already known) as a result of the conscious or involuntary effects caused by man's economic activity.

The practical interest in this is obvious. Technology is developing so quickly that even now the question arises -- what is the further fate of the abundance of carbon dioxide entering the atmosphere from fuel combustion, and cannot this accumulation of carbon dioxide, by increasing the "greenhouse effect", lead to a catastrophically warmer climate. Another example -- are the polar ice caps stable; would relatively warmer thermal conditions cause them to disappear or, on the other hand, catastrophically increase?

Many similar questions arise. Probably, the only method is to give them scientifically based answers by conducting numerical experiments simulating our atmosphere in changed conditions. One needs a universal physical and mathematical model of atmospheric circulation which would accurately describe not only conditions existing on earth at present, but other possible conditions. Can one test such model with such material? This is where planetary atmospheres are useful. By studying them we acquire a deeper knowledge of processes taking place on earth.

A Secret Is Revealed

Academician A. Mikhaylov (Pulkovo Observatory)

"Pravda", July 29, 1972.

Of all planets in the solar system the most enigmatic was Venus, whose atmosphere was discovered in 1761 by M. V. Lomonosov.

It was always shrouded in a thick layer of clouds of unknown composition; it attracted the attention of many scientists and aroused the imagination. There were many theories on the "Morning Star". There was even contradictory information on its rotation around its axis. In size, mass, density and gravity, Venus is more similar to earth than all other planets. However, owing to its proximity to the Sun, more than twice as much solar heat falls on one unit of its surface than that of earth, and this creates a high temperature in deep regions of the extremely dense atmosphere and, consequently, its surface is hidden from us by cloud.

Some information on the atmosphere of Venus was obtained from spectroscopic observations in the infrared region. It was shown that there was a predominance of carbon dioxide with a very small admixture of free oxygen. Beginning 15 years ago, radio observations gave more reliable information on the temperature and rotation of Venus. As one penetrates the planet's atmosphere, the temperature greatly increases and reaches hundreds of degrees centigrade in the nearest surface layers. Amazingly, it does not rotate very slowly, one revolution approximately every 243 earth /134 days, but in a direction opposite to that of planets around the Sun and the axial rotation of the majority of them.

A new phase of research into this mysterious planet has been made possible by the launch of Soviet interplanetary automatic stations. The first two (Venera-1 and Venera-2) passed close to it, and the Venera-3 reached the planet and penetrated its atmosphere, which was dense and hot. Later, the Venera-4 made the first

smooth descent in the atmosphere of another planet and provided details of its features. During these flights it was sometimes necessary to operate blindly, but nothing is conquered easily, most of all in science.

In May 1969, vehicles which separated from the Venera-5 and Venera-6, penetrated the atmosphere of Venus and determined its temperature, chemical composition and density. This was a great achievement for Soviet science. The information obtained allowed a vehicle to be built to withstand high temperatures and pressure. It was launched towards Venus by the Venera-7, and provided valuable information.

Apart from information on the atmosphere and temperature conditions, interplanetary stations have shown that Venus has no radiation belts, and its magnetic field is very weak. However, the intensity of cosmic rays due, probably, to its proximity to the Sun is noticeably greater than in near space.

The high temperature and great pressure deep inside its powerful atmosphere have set scientists and designers of automatic interplanetary stations, and especially their descent vehicles, an extremely difficult task: to produce instruments which would work perfectly at temperatures reaching 400-500° C, and at a pressure of up to 100 kg/cm^2, capable of withstanding g-force which occur when entering the atmosphere of Venus with a speed exceeding the escape velocity, and for Venus equalling 10.2 km/sec.

All these difficulties were overcome as the outstanding flight of the Venera-8 showed. The descent vehicle reached the surface

on the illuminated side of Venus and made a soft landing, for 50 min transmitted interesting information not only on the atmosphere, but on the surface itself which, was "sensed" in this way for the first time. The new experiment not only shows the high degree of development of Soviet science and technology, but once more confirms that the future is behind space work, and an important role can be played by them when investigating outer space.

One is amazed by the accuracy when correcting the station's orbit and landing it on the prescribed point of the planet. On the day of the landing Venus itself was visible from earth like a 10-kopek piece at a distance of 80 m. It would be difficult to find a sniper who could not only hit a moving coin at such a distance, but also choose a certain point on it beforehand.

It is difficult to overestimate the scientific and cognitive value of the new experiment. Some time is required to completely process the information obtained. But one can already safely say that our knowledge of the nature and properties of planets has been increased. Venus, the earth and Mars, belonging to the so-called earth group of planets, do not differ significantly in mass, size, density and distance from the Sun and motion around it. But their physical conditions, chemical atmospheric composition, and surface structure are widely different! The enormous difference in their nature has once more been shown.

The Birth of Mineralogy on Venus

Leningrad

"Moskovskaya pravda", July 28, 1972.

Professor D. P. Grigor'yev, a well-known scientist and the president of the International Commission on Space Mineralogy, described one of the experiments conducted by the Soviet Venera-8 as the first blow by the geological hammer on the hot rock of Venus. At the request of N. Konstantinov, a TASS correspondent, he showed the scientific value of "testing" soil on Venus and the prospects of such research for discovering the geological nature and evolution of our space neighbor. /135

As mineralogists, we are extremely interested in the first information on the atmospheric composition and physical conditions on Venus. The fact is that the atmosphere of planets is the result of the separation of gases by solid planetary matter. Therefore, analysis of the atmosphere allows conclusions to be made on the composition, condition and other properties of rock and minerals on Venus. This planet, as opposed to the moon and Mars, is a rich one. For example, whereas the moon does not have an air envelope and is, as it were, a hardened model of the earth's distant past, Venus, apparently, is undergoing an active geological evolution. After detailed study we met phenomena, which are taking place on earth much slower, and possibly, this will happen to our planet in the future.

The high temperature and abundance of carbon dioxide in the Venusian atmosphere cause several conclusions to be made on the planet's geological nature. Experiments in laboratories showed that it was possible to isolate minerals containing carbonic acid salts. On earth, one of the most wide-spread of these minerals is calcite -- the basis of limestone, covering large areas of the world. By heating calcite and quartz scientists observed the active formation of free carbon dioxide. A theory on this mechanism forming the atmosphere of Venus has been suggested by the well-known Soviet scientist and geochemist, Academician A. P. Vinogradov. He says that when this occurs a new mineral, wollastonite, is formed, which probably constitutes the surface of Venus.

A. P. Vinogradov estimated, for example, that if this happened on earth during its history so much carbon dioxide would have been isolated, and if it had not been required by vegetation, the pressure of the earth's atmosphere would have been 40 times greater than it is today.

Carbon dioxide can also be produced when heating dolomites, and the interaction of iron ore, a siderite with a number of other minerals. Both these minerals known on earth may be encountered on Venus.

There is much to be said for the theory of the unusual active volcanism on Venus which heats its surface and hurls into the atmosphere a huge amount of carbon dioxide. Volcanoes on earth are "colder" than those on Venus. But when they erupt, many thousands of tons of gas and a large amount of heat are produced.

We are witnesses of the birth of a new science -- mineralogy on Venus. The landing of the Venera-8 is helping to develop this science. Suffice it to say that only information on the density of soil can settle scientific quarrels on the formation of Venus. In its turn, this will affect our concepts of the geological history of the earth, which, in the final analysis, will help to throw light on laws governing the distribution of minerals.

Venera-8 Was Born Here

V. Smirnov (A "Pravda" special correspondent)

"Pravda", August 5, 1972.

A Report from the Design Bureau

The familiar roomy office of the head of the design bureau. /136 Nothing has changed since I was here last. Probably, only the photographs on the wall are new: the damaged disc of Mars surrounded by haze, recorded by the Soviet automatic station when orbiting the planet, and a picture of a tray with lunar matter brought back by Luna-20 ....

At the table are designers and workers of the plant's assembly department. They are talking about the Venera-8, which they designed and produced, in short, which was born here.

The deputy chief designer says, "Now, when the experiment has been successfully concluded, that stage for us is over. We are now solving other complex problems and looking ahead. But we can talk of the Venera-8. It completely accomplished its program and

gave much valuable information on the mysterious planet. This information has helped science to discover the nature of Venus.

However, the value of the experiment has not been exhausted. For designers, its success is the realization of everything they had conceived and planned. It was shown that our decisions and principles, which went into the design of the vehicle, were correct, as was the selection of material from which it was constructed and the methods of testing its subassembly units on earth. Valuable engineering experience was gained which will be useful when producing further automatic vehicles for investigating Venus ..."

Those taking part in the conversation returned to the days when the Venera-8 did not exist, and its descent vehicle could only be seen on drawings or in the plant workshop.

The leading designer continues the conversation. "The Venera-8 was a logical continuation of the previous Venera-7. However, the building of the descent vehicle was almost completely new. How were these important problems solved?

The vehicle was designed for prolonged work on the planet's surface. Therefore, there was a great need for thermal protection. This had to be maintained during all stages of the experiment, during the flight in outer space, after aerodynamic braking in the dense atmosphere owing to great g-force, and on impact with the planet's surface. Thermal insulation material must have a very low coefficient of heat conduction. After landing, it assumes the functions of thermal protection from the hot atmosphere. This is

also done by an effective refrigerant used in the descent vehicle. All this is to delay the vehicle's "thermal death".

New devices and additional scientific instruments were installed in the descent vehicle. Therefore, one had to reduce the weight, mainly by lightening the body of the vehicle. An experiment with the Venera-7 showed that there were reserves for economy. However, it was necessary to conduct research in calculating the strength of the load carrying shell. The theory for calculating the resistance to external pressure was also investigated. Why external? In engineering there were no examples for producing large diameter shells which "operate" in large external pressures and temperatures. The body of the vehicle is a sphere, or "globule" as it is sometimes called. If external pressure acts upon it as, for example, in balloons launched into the earth's atmosphere, then any inclination from the geometrical sphere could be corrected independently. But when there are great external pressures not even the slightest error is permissible in the spherical shape of the shell; it must /137 be perfect. Even a small deviation would cause the body of the vehicle to disintegrate.

The problem is complicated since several tens of "holes" for feeding external sensors, antennas, etc. must be made in the load-carrying part of the descent vehicle. Each one of these apertures weakens the construction and this must be compensated for. Nevertheless, the weight of the vehicle's body was considerably reduced.

All the sensors and sensing elements during the descent stage by parachute come into contact with the environment, but the

measurement equipment and radio transmitter are inside the "globule". The most complex problem is the sealing of the instrument module. If the hot atmosphere of Venus enters it the instruments will die. Normally, various types of rubber are used when sealing ground vehicles. Obviously, these are not suitable for a hot planet. Sealing assemblies for sealed conductors had to be made from high-temperature strength material. Prolonged operation of the vehicle on the surface of Venus shows that this has been successfully solved.

Those who test space vehicles are not boasting when they say that their work cannot be written as a newspaper report, but as a long novel. At first, individual parts of the space station are developed and tested, later they are assembled into subassembly units, and only after this is complex testing of the vehicle as a whole carried out. Here are a few examples of this complex cycle.

In the Venera-8 descent vehicle a new system for separating the parachute compartment and improving the parachute system was used. The parachutes were tested on a special test bench. This is a type of wind tunnel through which a gas flow heated to 500° is passed. Carbon dioxide, the main component of the Venusian atmosphere, is fed into the tunnel. In this way, sensors and film cameras were able to observe the behavior of the parachute system in conditions close to the actual ones.

The "globule" itself was tested repeatedly in a high-pressure chamber. Here, physical conditions were simulated where it falls onto the surface of the hot planet which has a pressure of more

than 100 atmospheres, and a temperature greater than 500°. When the vehicle lands there will be an impact when it meets the planet. Therefore, one must test its capability to "withstand" this impact. The landing of the vehicle was also simulated in this chamber by using special shock absorbers. The testers carefully studied how the equipment worked during such impacts.

But now it is time to assemble not a flight model of the vehicle, but one which is to be sent to Venus. This is a tense moment for engineers, foremen, technicians and plant workers." On one of the test benches set up on a factory street planted with trees, I saw the sign "Comrades! The success of the whole team depends on the quality of your work." These words are true. This is confirmed by one of the managers of the enterprise:

"The design of a space vehicle includes technical problems, and strict requirements for accuracy in producing components and assemblying subassembly units. The quality of the work is decided by the accuracy of lathe operators, welders, adjusters, assemblers, and their responsible attitude to their work. Space has no time for those who are indifferent. Without exaggeration I will say that our workers have performed miracles. This is because each one understands that he is responsible for how the vehicle works in space and the contribution it makes to Soviet science ..."

To Scientists, Designers, Engineers, Technicians, Workers and All Teams and Organizations Participating in the Construction, Launch, Flight Control and Landing of the Venera-8 Automatic Interplanetary Station /138

"Pravda", August 16, 1972.

Dear comrades!

Soviet science and technology has achieved a new outstanding success.

The laid-down flight program of the Venera-8 automatic interplanetary station has been completely fulfilled.

On July 22, 1972, after a four-month space flight, the Venera-8 automatic interplanetary station reached the planet Venus. The station's descent vehicle investigated Venus for the first time, descended smoothly in the atmosphere on the illuminated side of the planet and made a soft landing on its surface.

During the launch of the vehicle in the atmosphere and for a period of 50 min it worked on the surface of Venus and transmitted back to earth much valuable scientific information on the properties of the atmosphere on the day side of the planet, and the nature of rock on its surface layer.

This new space experiment once more clearly demonstrated the great possibilities of automatic vehicles for investigating outer space and planets of the solar system.

This outstanding achievement of Soviet science and technology was only possible due to the inspired work of the Soviet people, greeting the 50th anniversary of the formation of the USSR with new feats of labor. The Central Committee of the Communist Party

of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR warmly congratulate scientists, designers, engineers, technicians, workers, and all teams and organizations participating in the production, launch, flight control and landing of the Venera-8 automatic interplanetary station.

Long live the Soviet people -- the builders of communism!

Long live the Communist Party of the Soviet Union!

The Central Committee of the Communist Party of the Soviet Union.

The Presidium of the Supreme Soviet of the USSR.

The Council of Ministers of the USSR.

To the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR

"Pravda", August 16, 1972.

We, scientists, designers, engineers, technicians and workers participating in the construction, launch, flight control and landing of the Venera-8 automatic interplanetary station, report to the Central Committee of the Communist Party of the Soviet Union, the Presidium of the Supreme Soviet of the USSR and the Council of Ministers of the USSR on the successful completion of a new space experiment.

In this jubilee year of the Soviet State a primary task of the party and government has been carried out.

On July 22, 1972, the Venera-8 automatic interplanetary station, launched on March 27, 1972, after covering a distance of more than 300 million kilometers, set down on Venus a descent vehicle containing scientific equipment. During the parachute descent stage, investigation of Venus was carried out for the first time, and measurements were made to determine the illumination, pressure and temperature in the atmosphere on the surface of the planet on its day side. Information was obtained on the nature /139 of rock on the planet's surface layer.

The Venera-8 station's descent vehicle left on the planet pennants with the bas-relief of the founder of the Soviet State, Vladimir Il'ich Lenin, and the State Emblem of the USSR.

New information on the atmospheric properties on the illuminated side of the planet and measurement results on its surface will significantly broaden our knowledge of Venus and be a valuable contribution to the science of planets of the solar system.

We assure the Central Committee of the Party, the Presidium of the Supreme Soviet of the USSR and the Soviet government that we shall strive for new successes in the conquest of outer space for the benefit of Soviet science and technology, our people and the whole of mankind.

Venera-8: The Results of the Space Flight

TASS

"Pravda", September 10, 1972.

The 50th anniversary of the formation of the USSR has been marked by a new outstanding achievement of Soviet astronautics:

on July 22, 1972, the Venera-8 automatic interplanetary station completed its four-month flight and transmitted unique scientific information from Venus.

The Venera-8 station's descent vehicle contained pennants with the bas-relief of the founder of the Soviet State, Vladimir Il'ich Lenin, and a picture of the State Emblem of the Soviet Union (Fig. 25).

Fig. 25. Emblems with the bas-relief of V. I. Lenin and a picture of the State Emblem of the USSR, set down on Venus by the Venera-8 automatic interplanetary station.

The first research into Venus was conducted on the side of the planet illuminated by the Sun, when the descent vehicle of the Venera-8 station entered the atmosphere and landed on the planet. The parachute descent in the atmosphere of Venus lasted approximately one hour. After a soft landing, the descent vehicle worked for 50 min on the surface of Venus transmitting scientific information to earth.

The unique information on the properties of the atmosphere, the illumination on the planet and the nature of soil on its

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surface layer obtained during the descent and work on the surface is of basic scientific value.

The Soviet program for studying the solar system by using automatic vehicles is being successfully accomplished. The Venera-8 flight is an important contribution to science and a new step towards our understanding of nature.

The launch date and length of the flight were determined basically by the favorable, mutual positions of the earth and Venus. The station had to reach Venus at a time when the planet was quite close to the earth -- approximately 60 million kilometers. Since Venus's orbit is inside that of the earth, when the planets are approaching each other, the greater part of Venus turned towards us, between the Sun and the earth, is not illuminated.

A choice of landing site on a narrow crescent of the illuminated part of the planet visible from earth was limited by the descent vehicle's prescribed entry corridor in the planet's atmosphere. If the entry was too steep the vehicle could be destroyed by g-force, and if the entry was not steep enough it would pass the planet. Apart from this, the earth had to maintain reliable radio communication with the descent vehicle.

All these factors significantly limited the vehicle's landing area on the planet, its maximum diameter was less than 500 km. This called for increased accuracy of flight control. /140

Forecasting the station's movement and flight control was done by ground command and measurement facilities.

Determining the station's trajectory parameters was accompanied by radar measurement of the distance from earth to Venus. Trajectory measurement data and radio location of the planet reliably determined and forecasted the approach parameters of the station towards Venus.

A station trajectory correction was carried out on April 6, 1972. Further measurement and calculation showed that the descent vehicle would land in the calculated area of Venus with sufficient accuracy - therefore, a second correction envisaged by the program was not made.

During the whole flight, the station was oriented towards the Sun by panels of solar batteries (apart from the correction session and some communication sessions). In this way, the solar batteries and the thermoregulating system worked well.

A few days before the station reached the boundary of the atmosphere of Venus, the descent vehicle's instrument container was cooled to increase the length of research in the planet's hot atmosphere.

After 117 days of flight, on June 22, 1972 immediately before entering the atmosphere of Venus, a near-planet communication session was held with the station, during which scientific data and information on the state of on-board systems was transmitted, preparations were made for separating the descent vehicle from the orbital module, and trajectory measurement was carried out. During this, the coordinating computation center processed trajectory measurement information to calculate the moment when the vehicle entered

the planet's atmosphere, and correct the work of ground tracking facilities.

At 10 hours 40 minutes the descent vehicle was separated and /141
spent 53 min in the planet's atmosphere.

During the aerodynamic braking phase, the speed of the descent vehicle was reduced from 11.6 km/sec to 250 m/sec; the maximum g-force was 335 units and the gas temperature in the shock wave in front of the vehicle's body was more than 12,000°. However, the casing of the descent vehicle was well-shielded from high temperatures by its thermal protection.

When the g-force and the speed of the descent vehicle was reduced to the calculated amount, an on-board device was activated and gave a command for the parachute system to be used.

After the parachute opened, information was received from the descent vehicle on the parameters of the atmosphere of Venus and the condition of the on-board systems.

The parachute descent and transmission of information lasted approximately one hour, and at 12 hours 29 minutes, the descent vehicle made a soft landing on the side of the planet illuminated by the Sun.

The descent vehicle's on-board systems and scientific instruments continued working on the surface of Venus for 50 min; during this period measurement information on the parameters of the atmosphere and characteristics of the soil on Venus, and also information on the condition of on-board systems was transmitted to earth.

The Venera-8 Automatic Interplanetary Station

The Venera-8 automatic station was designed bearing in mind the scientific information of Venus and experience obtained during the production and flight of Venera stations.

As all the previous stations of this type, the Venera-8 (Fig. 26) consists of an orbital module and descent vehicle. The overall weight of the Venera-8 is 1,184 kg, the descent vehicle weighs 495 kg.

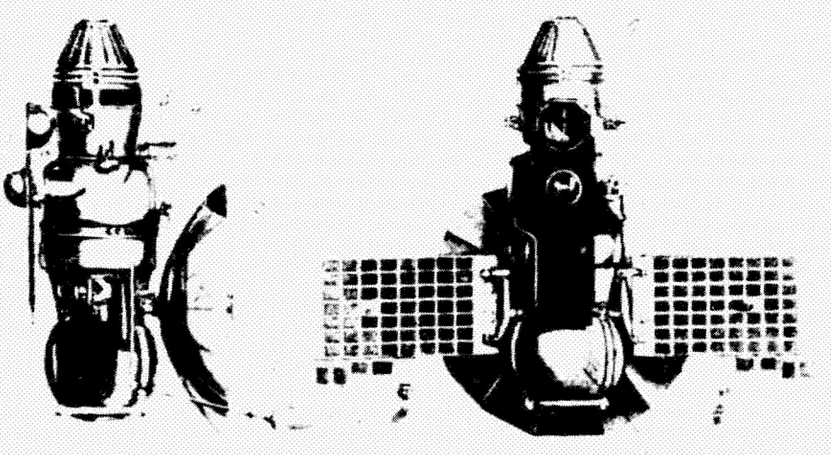

Fig. 26. The Venera-8 automatic interplanetary station. 1, 2, 4 - Astroorientation system sensors; 3 - Instrument module; 5 - High-directional parabolic antenna; 6 - Semi-directional antenna; 7 - Solar battery panel; 8 - Descent vehicle; 9 - Vernier engine installation.

The station's orbital module carries the descent vehicle to Venus. It is equipped with an astroorientation system, a control and temperature control system, energy supply and radio equipment.

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The vernier engine installation is fixed to the bottom of the module and the descent vehicle to the top. The orbital module contains optical instruments and servo elements for the astroorientation system, solar battery panels, semi-directional helical and high-directional parabolic antennas.

Communication with earth is done mainly via the semi-directional antennas; special radio communication sessions, using the high-directional parabolic antenna, are held with the station when it is at great distance or when there is a large amount of information to be transmitted. Here, the station is positioned so that the parabolic antenna is directed towards the earth.

The equipment is supplied by chemical sources of current and the solar batteries charge these up during the flight between communication sessions. The astroorientation system which controls the position of the station consists of optical and electronic instruments for solar, solar-earth and solar-stellar orientation, and automatic equipment and servo elements -- microjet engines.

The optimum thermal conditions of instrument containers of the orbital module and the descent vehicle were maintained by an active thermoregulating system, based on the circulation of gas carrying heat from the containers to the external emitting radiator. The thermal conditions of the remaining equipment /143
and elements were maintained by passive means: thermal insulation, special optical coatings, etc.

After the descent vehicle was separated, the orbital station was destroyed when it entered the dense atmospheric layers.

The Venera-8 descent vehicle underwent significant modification. As a result of the investigation of the atmospheric parameters by the Venera-7, the estimated values of the fully-factored load on the descent vehicle and the maximum temperature of the environment were reduced.

In this way, this lightened the construction of the Venera-8 station's descent vehicle. The reduced weight allowed for additional scientific instruments to be installed, and measures were taken to increase the operational time of the equipment on the surface of Venus.

The descent vehicle consists of an instrument module and parachute module. The parachute module, contained in the upper section, includes a parachute system, a radio altimeter, scientific equipment sensors and an on-board radio system antenna.

The descent vehicle's instrument module contains a radio technical and telemetry system, electrical supply sources, fans and other units of the thermoregulating system, automatic equipment and scientific instruments.

To create the required temperature conditions in the descent vehicle's instrument module, the efficiency of the external thermal insulation envelope was increased and heat absorbers, made of material with a high heat capacity, were installed inside the module. When the vehicle is heated they remove a considerable part of the thermal energy entering the instrument container, and by the

same token, guarantee the serviceability of the descent vehicle's instruments and systems for a relatively long period.

A new antenna system was used to communicate with earth in the Venera-8 station's descent vehicle, and consists of two antennas: a helical, attached to the upper section of the vehicle, and a remote one, led out of the module after the vehicle lands. During the descent stage communication is done via the first antenna, and after landing, periodic switching of the on-board transmitter from one antenna to the other is carried out on commands from the programming and timing device. This ensures the reliability of the descent vehicle's radio communication with earth, since, owing to the uneven ground on the landing site, one of the descent vehicle's antennas might not be directed towards earth (Fig. 27).

Fig. 27. The Venera-8 station's descent vehicle on the surface of Venus. 1 - Remote antenna (after jettisoning); 2 - Pressure and atmospheric temperature sensors; 3 - Illumination measurement sensors; 4 - Main antenna; 5 - Remote antenna (before jettisoning); 6 - Parachute (after jettisoning).

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The faultless operation of all the systems and scientific instruments of the Venera-8 and its descent vehicle was the result of careful ground development in conditions almost identical to those in outer space, and in the atmosphere and on the planet's surface.

Scientific Results

The Venera-8 was equipped with scientific instruments allowing a wide range of research to be made into the atmosphere and the surface of the planet's day side, and into the interplanetary medium during the flight.

The main aim when selecting scientific experiments for the descent vehicle was to obtain answers to a number of basically new questions on the physical and chemical characteristics of Venus's atmosphere and surface.

The descent vehicle's scientific equipment was designed for carrying out the following tasks:

-- research into the atmosphere (temperature and pressure measurement) on Venus's day side; /144

-- measuring the illumination in the atmosphere and near the planet's surface;

-- determining the wind speed at different levels in the atmosphere;

-- determining the ammonia content in the atmosphere;

-- measuring the g-loads occurring during aerodynamic braking;

-- determining the physical characteristics of the surface layer and the nature of surface rock where the descent vehicle landed:

Information obtained from this complex experiment is being processed, therefore, the results shown are preliminary.

The Venera-4, -5, -6 and -7 stations, which made a descent on the night side of the planet, measured quite accurately the temperature and pressure of the atmosphere at an altitude and down to the surface. A model of Venus's atmosphere was made as a result of this measurement and, as has already been said, was used when producing the Venera-8. Although days on Venus last approximately four earth months, on the basis of theoretical calculations and result of radio astronomical observations, it can be expected that the daily measurement of temperature near the planet's surface are small, however, this must be checked experimentally.

The Venera-8 station carried out direct measurement of temperature and pressure by using a sensor system during the descent from an altitude of approximately 55 km to the planet's surface and after landing. Altitude measurement above the surface using the on-board radio altimeter was carried out during the whole of the descent time.

The altitude above the surface was also determined from the hydrostatic equilibrium of the atmosphere by using measurement data of temperature and pressure, and by the equation of motion of the vehicle using a parachute with known aerodynamic characteristics. Additional information on the altitude above the surface can be obtained by calculating the vehicle's descent speed during the parachute phase which, in its turn, is determined from earth according to the radio measurement data of the vehicle's speed.

No noticeable differences in altitude profiles of temperature and pressure on the day and night sides of Venus were observed, which confirms the theoretical calculations of these characteristics. At the Venera-8 station's landing site the atmospheric temperature was 470 ±8° C, the pressure 90 ±1.5 kg/cm^2, which is very close to values obtained as the result of an experiment by the Venera-7 when it landed on the planet's night side.

When the descent vehicle entered the atmosphere of Venus during the aerodynamic braking phase, the g-force acting on the vehicle was measured depending on time. Since measurement of the g-force is determined by the distribution of atmospheric density according to altitude, this measurement data determines the values of the atmospheric parameters higher than the level in the atmosphere at which direct measurement was begun.

A key question when the Venera-8 landed was that of whether sunlight reaches the planet's surface or is almost completely held back by the atmosphere and clouds. In other words, is it light on Venus in daytime or is there continual darkness? The illumination in the atmosphere and on the planet's surface had to be measured. Therefore a special instrument, a photometer, was installed in the descent vehicle. The instrument was designed for measuring the illumination in a wide range of light flux values, which could be expected on Venus, and had to remain serviceable in very difficult conditions which exist in Venus's hot, dense atmosphere. Information on the strength of illumination was obtained during the whole descent stage and down to the surface. This unique information /145

proves that a certain amount of sunlight in the visible region of the spectrum arrives on the planet's surface, and there are noticeable differences between day and night. Preliminary evaluations of the nature of change of illumination according to altitude show that the atmosphere of Venus significantly attenuates sunlight. Quantitative analysis of these results is being carried out at present, and this will allow us to calculate a number of important parameters determining the optical characteristics of Venus's atmosphere.

As is known, the flight of the Venera-4 first determined the basic chemical composition of the atmosphere of Venus, which was subsequently made more exact by the Venera-5 and Venera-6. It was found that the planet's atmosphere consists of 97% carbon dioxide. The nitrogen content is no more than 2%, oxygen less than 0.1%, and water vapor near the cloud layer less than 1%.

At the same time, in spite of compiling some information on the composition and structure of the atmosphere, the problem of Venus's cloud layer is still unsolved. The lack of actual material gives rise to various theories which need to be checked experimentally. In particular, there are theories that compounds, containing ammonia (ammonium salts) could form the clouds. In this case, at altitudes lower than 48 km, one could expect a relatively large amount of free ammonia in the atmosphere.

Therefore, an instrument for determining ammonia was installed in the Venera-8. It was based on a method for recording the change of color of a specially chosen chemical reagent when ammonia

interacts with it. A fine-grained yellow powder was used as a reagent which becomes blue when contacting ammonia. The change of color was recorded by photoresistors.

The first measurement was made in the atmosphere of Venus at an altitude of 46 km, the second at an altitude of 33 km. Results of the experiment give basis to suppose that there was a small amount of ammonia in the atmosphere where the measurements were made. Its volumetric content was estimated at being 0.01-0.1%.

The influence of wind on the descent vehicle during its slow descent in the atmosphere by parachute was indicated when it drifted horizontally. Therefore, knowing the vehicle's radial velocity in relation to the earth, determined according to the Doppler shift of frequency and the vehicle's descent speed relative to the surface of Venus, which was determined independently, one can estimate the wind speed in the atmosphere. The Venera 8, in descent, measured the horizontal velocity component. At altitudes greater than 45 km this was more than 50 m/sec, decreasing to less than 2 m/sec at altitudes lower than 10-12 km. This measurement shows there is zonal (latitudinal) wind directed from the terminator to the day side, that is, towards the planet's proper rotation, and this is very important for understanding the dynamics of Venus's atmosphere.

Much attention was paid to studying the physical and chemical properties of the planet's surface by the Venera-8 in the Venus research program.

The dielectric permeability and soil density were determined by analyzing the level of radio waves emitted by the vehicle during descent, and reflected by the surface. Results of these measurements gave basis to assume that in the descent area the planet's surface area was quite loose, with a soil density rather less than /146
1.5 g/cm^3.

The results of measuring the content of natural radioactive elements in the surface layer of Venus where the vehicle landed are very important.

The nature of rock can either be determined by its full chemical or mineralogical composition. Apart from this, one can determine the nature of rock according to a number of separate chemical elements which are characteristic of a certain type of rock, for example, by the content of natural radiation elements in rock: uranium, thorium and potassium. Therefore, Venera-8 was equipped with a gamma-spectrometer which determined the content of radioactive elements according to gamma radiation in the surface layer of Venus. The gamma-spectrometer was installed inside the station and registered in the 0.3-3 megaelectron volt range gamma irratiation emitted by radioactive elements of the surface layer which passed through the station's shell nto the spectrometer's detector.

The gamma-spectrometer also measured the sum intensity of gamma radiation with energy greater than 0.3 megaelectron volts recorded by the spectrometer's sensor. In accordance with the station's work program, the Venera-8 was equipped with an instrument for measuring the sum intensity and carried out measurement both

during the descent stage in the planet's atmosphere, and after landing on its surface. Measurement of the whole spectrum of gamma radiation was only done on the planet's surface.

A number of measurements of the yields of rock with a known content of uranium, thorium and potassium was carried out on the ground for calibrating the instrument. The instrument was installed inside an analog of the Venera-8 station to simulate measurement conditions which would exist on the planet. Measurement was made on granite, basalt and other rock. Apart from this, the station's own background was measured above the powerful cover of rock which has an extremely low content of natural radio elements (dunite). This background is caused by gamma radiation of natural radioactive elements in the form of trace impurities in the construction material for the station and the instrument.

Three measurements were made of the sum intensity of gamma radiation when the vehicle descended in the atmosphere of Venus, and one measurement after it landed on the surface. The intensity recorded during the descent did not change significantly, and this shows the practical absence of radiations caused by short-lived isotopes formed as the result of cosmic rays when the station was in outer space flight.

After the descent vehicle landed on the planet's surface an increase in the sum intensity of gamma radiation was recorded, and this is linked with the addition of the effect from decay of natural radioactive elements present in Venus's surface layer.

The gamma radiation spectrum was measured while the station was on the surface of Venus. All this information from the spectrometer was read out twice. Measurement of gamma radiation spectra determined the amount of uranium, thorium and potassium content in the surface layer.

According to preliminary information, material on the surface near the landing site contained 4% of potassium, 0.0002% of uranium and 0.00065% of thorium, similar in content and in composition to the radioactive elements of granite rock. In this way, the Venera-8 detected rock which was relatively rich in potassium, uranium and thorium. In ground conditions this ratio of elements, mainly relatively rich in potassium, is characteristic of rock /147
which has undergone a secondary change when affected by different factors of the environment after primary melting from deep inside the planet. This information is extremely useful when one studies the geology of Venus. For the present, it has been obtained from a small area of the planet; further research will include other areas and conclusions will be made on processes taking place in the hard envelope of Venus, and the nature of its evolution.

Radiometric equipment in the station is designed for studying dynamic processes in interplanetary space, linked with solar activity, by systematic measurement of the composition, energy spectrum and variations of intensity of cosmic rays.

During the Venera-8 flight there was an anomalous increase of solar activity which greatly influences the level of intensity of cosmic rays in different energy intervals. Four powerful solar

flares, during which the solar intensity of protons with energies greater than one million electron volts and 30 million electron volts was significantly increased, were registered on a background of solar activity increase. There was also a significant reduction in the intensity of galactic cosmic rays arriving from distant regions of space. Similar anomalous increases of solar activity were recorded earlier, especially by instruments in the Venera-7, the Lunokhod-1, and the Mars-2 and -3.

Both during the flight and the approach to Venus measurements were made of ultraviolet radiation caused by neutral, atomic hydrogen scattered in outer space. In some regions of interplanetary space the intensity of this radiation increased by 2-3 times. The intensity of radiation, caused mainly by the background of bright blue stars, was measured in the narrow interval of the ultraviolet region of the spectrum.

The successful flight of the Venera-8 confirmed the correct choice of technical solutions adopted when designing this automatic interplanetary vehicle for working in the extremely complex conditions of the Venusian surface.

Scientific results obtained by the Venera-8 have made an important contribution to our knowledge of Venus, and have been most important to broaden our concepts of its nature.

This new achievement in space on the eve of the 50th anniversary of the formation of the USSR is a wonderful gift from Soviet scientists, engineers, technicians and workers.

Riddles of the Planets

"Izvestiya", October 18, 1972.

October 18 was the fifth anniversary of the day when the Venera-4 made its legendary finish and opened up a new era of direct research in the skies of other planets. Many readers of "Izvestiya" want to hear how our concepts of Venus have changed during this time. The editor asked Professor Yu. Surkov, a Doctor of Physical and Mathematical Sciences, to answer this request.

Research into Venus by Soviet space vehicles has significantly changed our notions previously held of its resemblance to earth. It was found that the atmosphere of Venus contains 97% carbon /148
dioxide, not more than 2% nitrogen, not more than 0.1% oxygen and, on an average, approximately 0.05% water. The temperature and pressure near the surface of Venus, first measured by the Venera-7, were 475° C and 90 atm, respectively.

Having all this data, scientists directed their efforts mainly to determine the mechanism for the formation of the planet's atmosphere which is so different from that of the earth.

The majority of them now believe that during the period of formation of planets from a protoplanetary gas and dust cloud they had other primary atmospheres. The basic components of these primary atmospheres were the lightest and most wide-spread gases in the solar system, hydrogen and helium.

However, with time the decay of natural radioactive elements took place; heat was formed and the interior of the planets was

fused. A stratification of matter took place on the surfaces which were the most fusible parts, which then cooled and formed the crust of planets. Simultaneously with the emergence of molten magma to the surface water vapors, carbon dioxide, ammonia, ammonium chloride, sulfur gas, hydrogen chloride, hydrogen fluoride and other gases formed and created a secondary atmosphere.

The further evolution of planetary atmospheres was determined by a number of factors. The lightest gases gradually drifted into outer space, and the most active interacted with rock. Solar radiation also played a great part in the formation of the atmosphere. Apart from this, the evolution of the atmosphere on earth was affected by animal and plant life.

The origin of the dense atmosphere of Venus was determined by its close proximity to the Sun. At some stage of its development even small amounts of water and carbon dioxide, probably, caused the "greenhouse effect" to develop (that is, conditions when solar heat penetrates the atmosphere and warms the surface, and the heat flux, emitted by the soil, to a considerable extent, is absorbed by this atmosphere). As a result, the surface gradually became warm, and this, in its turn, was accompanied by the further release of water and carbon dioxide into the atmosphere. This caused the "greenhouse effect" and, in this way, self-heating of the surface took place and a heavy carbon dioxide atmosphere was formed. Obviously, heat rising from the interior of the planet helped to develop this process.

The present-day atmosphere of Venus is in dynamic equilibrium with surface rock and is determined by temperature conditions existing on the planet.

Of course, in spite of the fact that much has been explained of the concepts we had of the atmosphere of Venus, many mysteries remain.

The main one of these is the cloud layer of Venus. The lack of sufficient information on the composition and formation of Venusian clouds gave rise to various theories and fantastic speculation. Among the enormous amount of volatile compounds which could be present in a cloud layer, the most often met are: water droplets and ice crystals, hydrates of iron chloride, haloid compounds of mercury, carbon monoxide and dust.

Until now, only the presence of water in the atmosphere of Venus has been reliably determined, which, at cloud level can be in the form of droplets or ice crystals, depending on the altitude above the surface. Apparently, clouds of Venus are formed not only from water but have other components. Since in the planet's atmosphere (especially in the cloud layer) there must be some vertical movement of "air" masses, naturally, there will also be transition zones where either the ice crystals melt or rain falls when the cloud layer descends. Of course, the area where rain falls does /149 not extend to the surface itself, but only to a level where pressure reaches 5 atm -- below this, water will again become vapor.

There are serious arguments in favor of the possible existence of ammonium clouds. Ammonia, like other gases, is formed as a

result of volcanic activity. When it interacts with carbon dioxide and water ammonia forms compounds which are white, crystal substances, and easily decompose when heated. The density of ammonium clouds must be significantly higher than aqueous ones.

Other cloud models are being examined.

Another problem which we have started to solve is the origin, evolution, present-day composition and formation and properties of Venusian rock. In particular, special interest is being paid to the question of whether a stratification process of matter on the surface took place on Venus and, as a consequence, is the crust similar to that of the earth. The answer to this important question can only be given by direct research into the composition, structure and properties of the Venusian rock itself by using automatic stations. Naturally, this research requires much time and effort. The problem is made more complex due to the fact that on Venus, owing to the special conditions on the surface, rocks can significantly differ from those on earth, in spite of the similar processes taking place when they were formed.

In particular, these suggestions are substantiated by research carried out into lunar matter brought back to earth. According to ideas now being considered by scientists, apparently, the same processes of "internal development" which occurred on earth occurred also on the moon in its distant past. At the same time, there are a number of features, in particular, the significantly smaller size of the moon, which had to be reflected in the formation of surface lunar rock. As a consequence, as research into the soil brought

back by Luna-20 showed, apparently, the majority of the lunar surface is covered by anorthosite rock, of which there is relatively little on the earth's crust. As is known, the main component of the earth's crust is basalt rock, which is only found on the moon in the mare regions, occupying about one-fifth of its surface.

Analysis of information transmitted by Venera-8 showed that the planet has a rock relatively rich in natural radioactive elements -- potassium, uranium and thorium. This amount of radio elements on earth is contained in granite which covers continents on our planet, but this rock has a density of approximately 1.5 g/cm^3, which is significantly lower than that of our granite, which is 2.4 g/cm^3. The fact that the surface of Venus is made from leaky and, probably, loose rock, relatively rich in radioactive elements, indicates the existence of a process of deep re-shaping. The future will tell whether this rock is characteristic of the whole surface of the planet and how it originated and evolved.

Finally, in the future much attention will be paid to the study of the internal structure of Venus. The great interest in this problem is also caused by the fact that we know little of the internal structure of our own planet. As for Venus, at the present time we have hardly any reliable information of its structure. Apart from this, flights of the first automatic stations to Venus showed that there were no noticeable radiation belts or magnetic field. Therefore, apparently, Venus does not have a core like the earth. This makes the problem even more interesting. In fact, the moon,

Venus and Mars do not have a noticeable magnetic field; this is only seen on earth. What is its origin and how did it change during the whole course of the earth's history? For example, the magnetic field on the moon, in its distant past, was 10,000 times greater. At what stage of development is each one of the planets of the solar system in this respect? Finally, what caused the appearance of a biosphere on our planet? When we know all these things we shall understand our own planet better, its past, its present and future. /150

B. RESEARCH INTO MARS

The Planet Tells Its Story

"Pravda", January 9, 1972.

The Soviet Mars-2 and Mars-3 automatic stations have been working for two months in orbits around Mars. Scientific instruments in the orbital stations are investigating the planet and the space surrounding it. Scientists are accumulating the first results and compiling programs for further experiments. We invited a group of workers from the Space Research Institute of the Academy of Sciences of the USSR into the editorial office and asked them to tell us of the work of scientific instruments in the interplanetary stations, and some results which have been obtained so far.

At our "round table" are: Yu. K. Khodarev, a Doctor of Technical Sciences and the deputy director of the institute;

Professor V. I. Moroz, a laboratory head; V. G. Kurt, a Doctor of Physical and Mathematical Sciences and a laboratory head.

Yu. K. Khodarev speaks first. He reports on the complexity of the problems solved during the orbital flight of both stations:

"If one formulates these problems on a large scale, one must isolate the following. The first -- is the research into the surface of Mars, its atmosphere and the processes taking place there. The second -- is the study of Mars as a planet as a whole -- show its formation features, and the evolution of its development in the solar system which, in the final analysis, will help us to understand the nature of earth. The third -- is to answer the question of whether there is life on Mars. Of course, we are not taking of Martians, but the possibility of detecting life or traces of it, however primitive.

The instruments in the stations must provide us with information on the physical conditions on the surface of Mars and in its atmosphere. We are interested in the relief and characteristics of the surface in various regions, information on pressure, humidity and temperature. We wish to study in detail the composition and structure of the planet's upper atmosphere, the physical conditions in the close vicinity of Mars, and also the nature of its interaction upon the surrounding interplanetary medium. Incidentally, the latter will give us a concept of Mars and its structure as a planet as a whole.

The orbits of the Mars-2 and Mars-3 stations pass close to the planet's surface above its southern hemisphere. This will

allow observation and measurement to be made in areas which have been studied least of all. The fact is that in observation from earth, even in the most favorable conditions, one can only satisfactorily determine the character and relief of the surface for the limited equatorial region of Mars. The best maps, compiled from these observations, allow us to study (and very approximately) the belt from 20° north latitude to 10° south latitude. We know little of the appearance of Mars beyond this belt -- in latitudes where seasonal changes are observed. Apart from this, the orbits /151 of Mars-2 and Mars-3 space stations will allow us to see the night side of Mars, which is inaccessible from earth.

At the present time, both stations continue their work and are giving us new information. Measurements have been made of the atmospheric humidity and the surface temperature in various regions of the planet. Photometery has been carried out into the atmosphere and surface, and photographs of Mars were taken from orbit and sent back to earth. It is worth noting that in December measurements were made during a strong and unusually prolonged dust storm covering large areas of the planet. However, this "present" from Mars will give us new, interesting information".

What are the first scientific results obtained during the experiment? This question is answered by V. I. Moroz:

"Even during major oppositions, when the distance between the earth and Mars is reduced to a minimum, the largest telescopes only give a very rough picture of the physical conditions on Mars. For example, the planet's surface temperature according to its infrared

radiation was only measured from earth with averaging over very large areas hundreds of thousands of square kilometers in size. The Mars-2 and Mars-3 stations are equipped with small instrument, an infrared radiometer, which measures the averaged temperature of areas 10-20 km in diameter.

During one of the sessions a temperature was recorded along a route extending from 58° south latitude, 330° longitude to 30°north latitude, 190° longitude. The highest temperature was recorded near the midday region. Of course, this is only considered high in the relative sense of the word: it equals -20° C. All the remaining points were colder. On the planet's night side the temperature falls to -90° C.

A small increase in temperature (by 10-15°) was noticed beyond the terminator (the boundary between day and night) in the Cerberus region. Such small temperature irregularities can be explained either by the increased thermal lag in different regions, which is linked, for example, with the exposure of rock, or volcanic activity. As a whole, temperatures measured in this session, are lower than expected, obviously due to the fact that the surface was covered by a dust storm, and radiation from it during measurement was attenuated by dust clouds.

"Photometric profiles" in three regions of the spectrum: were obtained when using a visual band photometer: red, blue and ultraviolet filters were used. The optical system made it possible to examine Mars in the plane of the satellite's orbit from the edge of the disc to the edge. This measurement [illegible] red filter

shows the significant fall of brightness near the limb of the planet and a smooth one near its terminator. The dark regions were completely invisible due to the dust storm.

Recordings with the ultraviolet filter showed a number of interesting details of atmospheric origin: an increase of brightness near the limb and the terminator, and in the region with a longitude of 220° and a south latitude of 15° a bright cloud was observed stretching for several hundreds of kilometers. This cloud consists of small particles which scatter light more effectively in the ultraviolet than in the red region. It is obviously higher than the dust clouds.

A photometer, determining the intensity of carbon dioxide bands, is designed for studying the planet's relief with respect to the optical thickness of the atmosphere, and in a dust storm cannot accomplish its main task -- measuring the depth of the atmosphere. /152 When the storm ends it will be possible to compare the results obtained in normal conditions with those at present and, in this way, determine the altitude of dust clouds.

An instrument, designed for optical measurement of humidity, showed there was a very small content of water vapor (at least, 1,000 times less than in the earth's atmosphere). Apparently, the instrument did not examine the lower layers of the atmosphere owing to the dust storm.

Similar measurement was made in sessions at the end of December. Interpretation of results has only just begun, and the equipment is working normally. There is reason to assume that the dust

storm is dying down at the present time. On photometric recordings, obtained with a red filter, one can see shading corresponding to Martian "seas", which earlier were completely indistinguishable. However, on recordings using an ultraviolet filter bright clouds were again recorded "

Apart from optical observations of the surface and lower atmosphere, the Mars-2 and Mars-3 stations are carrying out investigation into the upper atmosphere -- its luminescence at altitudes greater than 100 km. V. G. Kurt tells us about this:

"Complex physical and chemical processes, in which atoms, molecules and ions take part, occur in the upper atmosphere of the planet. Molecules of carbon dioxide disintegrate (dissociate) when affected by solar ultraviolet radiation with a wavelength shorter than 2,000-3,000 angstroms. As a result, there is a predominance of carbon dioxide near the surface of Mars, and in the upper atmosphere of the planet are found carbonic oxide, ions of carbon dioxide and atomic oxygen. Apart from this, there is a very small amount of water vapor. Water vapor also disintegrates when affected by solar ultraviolet radiation, and as a result, hydrogen atoms appear in Mars' upper atmosphere. During the absorption of solar ultraviolet radiation, the upper atmosphere heats up. The temperature at altitudes in the order of 200 km increases to 300-400° Kelvin -- much less than on earth. However, hydrogen atoms, the lightest in the Martian atmosphere, may leave the upper atmosphere of the planet and rise into the interplanetary medium, since gravity is three times less than on the earth's surface.

These atoms form a hydrogen corona, earlier discovered near the earth and Venus. All these atoms and molecules in the upper atmosphere of Mars are intensively scattered by solar ultraviolet radiation in orbit. By observing the luminescent in individual, characteristic lines one can calculate the density of components of the upper atmosphere of Mars and build a model of it.

Instruments recording radiation in three bands of the spectrum, containing lines of atoms of hydrogen, oxygen and argon, were fitted into the artificial Mars satellite for this research. The first observations showed that radiation in hydrogen lines extends to very great altitudes, exceeding the radius of the planet (3,400 km). Heavier oxygen atoms are concentrated near the surface up to altitudes of 600-800 km.

To facilitate measurement, the field of vision of ultraviolet instruments when satellites pass in the region of the pericenter of the orbit is directed to the "horizon" of the planet, that is, relative to the surface of Mars. In this way, a large number of atoms can be observed "on the beam of vision" and the resolving power can be significantly increased. We hope that observations will not only determine the density of atoms in the upper atmosphere of Mars, and its temperature, but trace the changes of these characteristics. Similar research is being done by our American colleagues with the Mariner-9. We have already received the first information from them and can compare results. Meanwhile, we only /153 have information on the intensity of illuminescence in individual spectral lines. Labor-consuming machine computation is required

to determine the density and temperature. Complex, mathematical processing of measurement lies ahead, and then theoretical models of the Martian atmosphere can be built. However, it is already clear that however paradoxical this may seem, the upper atmosphere of Mars is more similar to the atmosphere of Venus than the upper atmosphere of earth. Apparently, this is linked with the fact that there is a predominance of carbon dioxide in the atmosphere of Mars and Venus".

Yu. K. Khodarev winds up the conversation:

"Hence, you see that the results obtained are extremely interesting. The Mars-2 and Mars-3 continue their flights. I need only add that the first results obtained to date, and information of subsequent measurement will require careful processing, analysis, and study. Long months of work are ahead before the "raw" material received by the stations is converted into relief maps or temperature distributions, and before a corrected model of the atmosphere is built. The processed results must be generalized and compared with others which we already have. We are not expecting sensations. The long-time consuming work continues".

Reconnaissance of the Magnetic Field

"Izvestiya", January 8, 1972.

During the six-month flight to the distant planet, the Soviet Mars-2 and Mars-3 automatic stations investigated the magnetic fields of interplanetary space. Now they are studying them during

the flight in near-Mars orbit. The "Izvestiya" correspondent asked Professor S. Pikel'ner to tell us what the research into planetary magnetic fields means to science.

Among planets of the earth group, including Venus, Mars, Mercury, and with reserve one can say our own planet's satellite, the moon, the earth is unique since it has a relatively strong magnetic field. Many scientists believe that this was the reason for life on earth. The "magnetic shield" protects our planet from lethal flows of charged cosmic particles.

According to present-day theories, the earth's magnetic field exists owing to motions in the liquid core and the earth's rotation. Generally speaking, the magnetic field, apparently, was in the solar system from the very beginning, when interstellar gas had been compressed and the Sun had formed. At first, when the planets were formed solid particles conglomerated, forming "stones" of an asteroid type, and later these were united into a compact whole. But the planets which were coming into being could not retain the strong magnetic field sufficiently. In time, the heat caused when radioactive elements decayed caused a stratification of matter. A liquid core was formed, inside of which fused masses generating electricity constantly moved in the weak, primary magnetic field. Since the planet was rotating, this motion became rather asymmetrical. Therefore, a stronger magnetic field was produced. This process is similar to the work of a "dynamo".

If this theory is true, the presence of a magnetic field on any planet means it has a liquid core and relatively rapid rotation.

The moon has no noticeable magnetic field. It is too small to /154
accumulate a sufficient reserve of heat to fuse rock in its core.

Venus is practically the same size as earth and could be expected to have a liquid core and, consequently, a magnetic field. However, automatic stations did not detect a noticeable magnetic field. Apparently, this can be explained by the fact that Venus rotates very slowly around its axis. "A day on Venus" equals 243 earth days.

In size, Mars lies between the moon and earth and rotates just a little slower than the earth. However, measurements give a negative result. This is also important for science, and leads one to believe that Mars has no liquid core. The lack of a noticeable magnetic field on Mars provides theorists with new "food" for thought.

It is known that there are magnetic anomalies on earth, for example, Kursk. The absence of a general planetary magnetic field does not mean that planets do not have local fields. By using vehicles which can land on Mars and move around there, in time, a detailed magnetic survey of the planet could be made. It would be interesting to study rock capable of storing information on a magnetic field for a prolonged time. If Mars previously had a magnetic field, one could determine how this changed during millions and even billions of years.

From Orbits Around Mars

"Pravda", January 23, 1972.

The long-range space communication center, 22. (TASS). The Mars-2 and Mars-3 automatic interplanetary stations are continuing to orbit around Mars. On January 22 the Mars-2 completed 74 revolutions around the planet, and the Mars-3 four revolutions.

The stations are observing the surface of Mars, its atmosphere and surrounding outer space. According to instrument readings, in some regions there have been signs that the dust storm, which has been continuing on Mars for several months, is dying down.

However, the dust storm is still making photography and scientific measurement of the planet difficult. At the same time, prolonged systematic observations which are being made in the direct vicinity of this unusual and powerful natural phenomenon are of great scientific interest. In particular, it was seen that in some areas the upper boundary of the dust clouds is 6-8 km higher than the average level of the surface of Mars. Owing to the low transparency of the planet's atmosphere, caused by the dust storm, details on the surface can only be reliably distinguished in some photographs taken of areas where conditions are more suitable (Fig. 28).

Scientific instruments in the stations are measuring the surface temperature of the planet, the humidity, the brightness and other characteristics of its atmosphere. The research conducted from areas at the pericenters of the orbit is very important. A series

Fig. 28. A photograph of Mars. The mountainous area and foreland in the equatorial region of Mars (a photograph taken in the evening when the Sun was low).

of measurements has been made along tracks from the southwest to the northeast and from the day side of Mars to the night side. This research almost completely covers the unstudied regions of the middle latitudes of the southern hemisphere (from the 65th degree south latitude), the equatorial belt and regions in the northern hemisphere (up to the 20th degree north latitude).

In this way, the Mars-2 /155 and Mars-3 stations can obtain detailed information on areas of Mars which are inaccessible when one uses astronomical observation from earth.

The latest measurement confirms that the temperature near the terminator (the boundary between day and night) is -80-90° C. Some sections of the surface are 10-15° "warmer" than surrounding areas. The maximum recorded daytime temperatures in the middle latitudes of the southern hemisphere are -15 - -20° C. The on-board systems and scientific equipment in the Mars-2 and Mars-3 are working normally. Photographs and other information transmitted by the

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Mars-2 and Mars-3 are being processed and carefully studied in scientific institutes of the Soviet Union.

Science of Life

B. Kozlov, a Candidate of Technical Sciences and a senior scientific worker at the Space Research Institute of the Academy of Sciences of the USSR

"Sotsialisticheskaya industriya", January 26, 1972.

The question of the existence of life beyond the earth is extremely important for science. If we could detect some life-forms on another planet, let us say Mars, this would be an outstanding discovery. Judge for yourself: if life occurred independently and exists on two planets in one system, apparently, it /156 should be found quite extensively throughout the universe.

Similar suggestions have been put forward earlier. The present-day level of technical development will allow us to test them practically: this means sending automatic stations into orbit around planets and landing descent vehicles on the surfaces of them.

It is true, the first disappointment was when vehicles investigated Venus. The results of direct measurement of the parameters of the Venusian atmosphere showed that the temperature and pressure registered near the surface of the planet were so great that the existence of life, as we know it on earth, was very improbable. Hence, there is a greater interest in Mars. Conditions there are not so severe. At least, not so severe as to completely rule out all possibility of life (for example, the existence of microorganisms

or even plants). Special experiments show that many microorganisms have an amazing adaptability. They can withstand temperature changes in very wide ranges, from -60-100 to +80-100°, do not die in great pressure differentials -- even in an almost complete vacuum, and they can survive in atmosphere containing acid and alkaline vapors.

It is true that in these conditions life, as it were, stops. But one only has to improve the environment and it again revives. For example, it was shown that the simplest life-forms can exist even in lunar conditions. Hence, there is a theory according to which life can be transferred in spore form through outer space from one planet to another. But in order not to commit an error in the conclusions, one must always remember that the most favorable conditions in themselves still mean nothing. At first, life itself must be born, and this is a completely different thing!

It would appear that science has an extremely simple task: one only has to sent to Mars a scientific station with the appropriate equipment which would prove or disprove the existence of life. However, there is a serious obstacle even when setting such a problem. It appears that scientists still do not agree as to which signs of life must be considered basic and determinant. Some believe that such signs are the ability for cells to grow, some believe that it is more important that they divide, some give preference to metabolic processes, and others believe in the ordered structure inherent in living formations.

If we wish to send special instruments to Mars for detecting life, we must assume that it is basically similar to that on earth. In other words, we must accept that the basic chemical element for it is carbon and acid is its oxidant. We have no other alternative, since science on earth has no information whatever on life having another base. It is true that for some scientists this assumption is arguable: they believe that silicon could take the place of carbon.

An equally complicated task is to choose a place and a time for conducting research. Again, from analogy with the earth, it can be assumed that life on a planet must be found in places which have been selected due to their favorable conditions. It simply cannot exist in other areas, especially if life is not wide-spread over the planet. The conducting of tests will take a relatively long time. On Mars it would be tempting to choose the "local" spring and summer in order to attempt to discover the reasons for the periodic, seasonal changes of color and brightness of some parts of its surface.

What equipment is needed to detect life? What parameters must it register? Scientists and exobiologists believe that important signs of life could be chemical composition, metabolism, growth, appropriate reactions to external stimulation, the specific ordered nature of a microstructure, its changes over time and finally, reproduction. But, since carrying out experiments on such a wide program could scarcely be accomplished immediately, at first, obviously, one must limit oneself to some signs. /157

For instance, experiments to detect metabolism are very complex and special equipment must be used. Growth processes are relatively simple to detect, especially if one takes into consideration the ability to living microorganisms to produce carbon dioxide. It is not easy to produce, especially in specific quantities and during certain stages of development.

The orderly nature of a formation and dynamics of its changes are important along those signs of life shown above. Special microscopes working "in tandem" with television devices are needed to obtain images of fine microstructures. The greater the magnification of these instruments, the more reliable will be the results of observations. From this point of view, the electron microscope which can magnify tens and even hundreds of thousands of times is beyond compare. But it is complex, unwieldy and capricious. It is not easy to produce a preparation for it. Good results can also be obtained from the optical microscope, especially if one uses a "lighting" not only by visible but, for example, ultraviolet rays.

Which is the best microscope to use? It is believed that the probability of detecting life (if, of course, it is present in samples taken for research) using an electron microscope is almost 100%, an optical microscope 10% and when using chemical analysis methods only 1%.

There are strict requirements for sterilizing space equipment and instruments when conducting experiments for detecting life. Obviously, there is no sense in flying to another planet to detect

there microorganisms brought from earth. How can this be avoided? It is very difficult. We spoke above of the amazing abiliby for microorganisms to survive. For example, it is impossible to heat instruments to 500° or immerse them in nitric acid! This is why it will be simpler to detect life than prove that it was not brought there by the equipment used for carrying out the experiment.

These are by no means all the difficulties which must be overcome to detect life on other planets. The successful solution of this problem will depend on preliminary investigation -- on the results of studying the physical and chemical conditions on the planet and surrounding space. This will not only enable the most suitable areas to be chosen when searching for life on the planet, but will give an approximate estimation of what can be expected. The Mars-2 and Mars-3 are conducting such research at present.

Conversions of a Signal

V. Pokras, a Candidate of Technical Sciences and laboratory head at the Space Research Institute of the Academy of Sciences of the USSR

"Pravda", January 30, 1972.

Launching a space vehicle and sending it into satellite orbit /158 of the earth, moon or Mars is not an end in itself, but a means of studying the world around us. We receive most information on earth from radiotelemetry systems in orbit. Some of this information gives the condition of the vehicle's ancillary systems and their modes of operation. This information is analyzed and used for

controlling space vehicles. Another large part shows the progress of scientific experiments and, in the final analysis, is the source of new knowledge on objects investigated.

Normally, signals arriving from space stations are repeatedly converted, until they are scientifically evaluated. The Mars-2, Mars-3 and Luna-19 have many sensors measuring different physical values. Some of these change quickly, others slowly. The frequency for receiving these readings is chosen accordingly. For example, if one is studying the change of temperature in a room using a normal thermometer, there is no need to look at the scale every half second or even every few seconds: the temperature in this time will not change by an amount which a room thermometer can register. This is also true of space vehicles, where multi-stage commutators interrogate some sensors tens of times per second, and others only once per minute.

What happens if readings of a certain instrument change very slowly, but occasionally become more active? In this case, how often does one interrogate it for information? Obviously, the interrogation device itself must allow for the "behavior" of the measured physical value by adapting itself to the speed of its change. A system such as this is successfully working in the Soviet-French "Stereo" experiment in the Mars-3.

The use of multi-stage commutation and self-adapting systems uses the energy of space stations more effectively: the number of measurements is reduced without detriment of the completeness of the information. It is true that the structure of information

transmitted to earth is becoming more complex, but present-day ground, processing systems are successfully analyzing measurement obtained from hundreds of sensors in this difficult sequence.

During communication sessions with a space vehicle, millions of measurements are transmitted to earth, received by ground stations, recorded on magnetic tape and fed into processing systems. These systems are a huge complex of all types of equipment, including several large, high-speed computers.

Ground processing begins with a careful, comprehensive check of incoming signals. Interference in the path of radio waves, the slightest malfunction of a complex on-board or ground collection complex, or a transmission or reception failure can result in some information being incorrectly interpreted. This phase is crucial, and although the responsibility is assumed by computers, it sometimes happens that they cannot cope in very difficult situations and "ask" specialists to intervene. Of course, it is simple to ignore these measurements which complicate life, however, the interests of science and the unique nature of experiments conducted forbid this. Everything must be deciphered and evaluated!

Information has been received and analyzed which casts some doubts on the measurements points. Now, one can isolate the whole mass of information from orbit into readings of individual sensors or groups. This operation, which required many months of work, is done by a computer accurately in minutes.

Another important factor is that information from equipment /159
arrives on earth in certain conventional units. In some instances

it is very simple to convert these to physical values -- only a few arithmetical operations are required, however, in some cases one must examine the readings of tens of sensors together and use not only arithmetic but logical analysis. However, it is little to know that the measured temperature equals such a value. When and where in space was this information received? In order to "tie in" the measurement to time and space coordinates, the information of trajectory measurement and readings of special on-board clocks are used, which fix and transmit the accurate time of measurement in the form of electrical signals using a radiotelemetry system.

When investigating many physical processes and phenomena it is important to know in which direction the scientific instrument's sensor, at a certain point in space, was "looking". Therefore, simultaneously with the processing of "radiotelemetry", orientation of the space vehicles is done, for example, relative to the surface of Mars.

Now one can combine scientific measurement with trajectory and orientation information, and provide additional information relative to physical conditions, in which measurement was made, required for each scientific experiment. Only then the final stage of initial processing begins: the information takes on a form convenient for the experimenters. The machines draw graphs, print tables, and record information on punched tapes and magnetic tapes.

All these stages, which are normal for "ordinary" earth satellites, become more complex for Mars-2 and Mars-3 stations. For

the first time, signals from satellites of another planet which were processed arrived not once during the experiment, but regularly. To a nonspecialist, it is clear that it is more difficult to measure and calculate the orbit of a Mars satellite than an earth satellite. A new telemetry system has considerably increased the amount of information transmitted.

Not only the amount of measurement has increased, but there has been a saturation of information and its structure is more complex: this is the first time that such an amount of scientific research has been done simultaneously.

The Earth Wheels of Martian Automatic Control Units

Amos Aleksandrov, Doctor of Technical Sciences
("Novosti" Press Agency)

"Moskovskaya pravda", February 6, 1972.

From the moment when the Soviet Mars-2 and Mars-3 automatic scientific stations were launched in May 1971 until the present time they have been controlled by the Long-Range Space Communication Center.

These new vehicles differ considerably from scientific stations produced earlier for investigating far space.

First of all, they are self-sufficient. Instruments were used for the first time for continuous solar-stellar orientation, as was an autonomous space navigation system. The stations are equipped with on-board digital computers.

But the "independence" of the Mars stations does not simplify the work of the controllers on the ground. The role of the command and instrumentation complex is still significant if only because of the extremely complicated conditions and problems of these flights.

The work of all services and facilities participating in the /160 flight control is combined and coordinated by the operational control group.

Control of the Mars-2 and Mars-3 can be divided into three basic stages:

-- the flight from earth to Mars;

-- the final flight to Mars, separation of the descent vehicle, the soft landing, transmission of information from the planet's surface, injection of the stations into satellite orbit around Mars;

-- the flight in near-Mars orbits.

During the flight stage the planned trajectory was maintained, the necessary corrections were made, the load of operation of the on-board systems were checked, and scientific information was received. More than 230 communication sessions were held and 5,000 commands were issued.

The duration of communication sessions varied from several minutes to several hours.

An important role in the long flight to Mars was checking the condition of the scientific stations by telemetry information. Recommendations were compiled to maintain the serviceability of on-board units and systems.

The station's power engineering was carefully checked and the necessary charge and discharge energy balance was maintained.

Ballistics also played an important part. It controlled the flight path, determined the time for corrections to be made, calculated the amount of thrust and the length of time which the vernier engines should work. Ballistics forecast the motion of the stations and prepared target instructions for the tracking and control facilities.

Two radio channels were used for communication with earth. A narrow-band in the decimeter range, designed mainly for trajectory measurement and transmitting telemetering information. A wide-band, in the centimeter range, for transmitting scientific and phototelevision information.

As the stations moved away from earth they were more difficult to control. The time from the moment when a command was given to the station until the signal arrived and it was executed, towards the end of the flight, reached 15 min.

Radio signals from the stations became weaker. They had to be isolated from noise, decoded and amplified.

Whereas many controlled elements in the flight stage had been more or less developed in previous flights to Mars and Venus, the control during the approach flight and in the near-Mars stage of the flight had not been done previously. All the control operations during these stages were strictly determined by time and were extremely dependent on each other. For example, to carry out the third (approach flight) correction it was important, in the short

time available, to carry out trajectory measurement, process this, and transmit to the station the final data which made more precise that already in its "memory". Then, the readiness of the autonomous systems to carry out independently corrections and subsequent maneuvers was checked.

After the maneuver, the descent vehicle was separated from the Mars-3. The descent vehicle's autonomous control systems supplied the necessary entry angle in the atmosphere of Mars. This is most important to carry out a soft landing successfully.

After separating the capsule and the descent vehicle the retrofire rockets in the orbital stations were switched on and they went from flight trajectories into artificial Mars satellite orbits.

The Mars-3 took up a position relative to the vehicle approaching the surface of the planet, which allowed it, when possible, to receive from it information and record it on the on-board memory.

An additional radio channel was used for transmitting information from the descent vehicle to the Mars-3 orbital station. The station's memory recorded the information, and afterwards transmitted it back to earth. /161

Telemetering information was received continuously on the condition of the station's systems and on the operations they were planned to conduct. As a result of information received, if necessary, appropriate corrections could be made to the program sessions which had been calculated.

Another task was to specify quickly and reliably the landing area and determine the orbital parameters of the new Mars satellites. Control of the Mars satellites was additionally limited by the so-called "radio fading": when the stations went behind the planet and could not be reached by the ground radio complex.

The schedule for the interworking of all groups taking part in the work -- the control, ballistic, telemetering, diagnostic, the ground radio facilities group, computation centers and television and communication facilities -- was calculated to fractions of a minute.

At the present time, the third stage of controlling the station's flight, in near-Mars orbits is continuing.

The control of each station is "individualized". This is because of the significant differences in their orbits and sum differences in equipment and modes of operation of on-board systems.

A control plan is compiled for each station, dictated by the tasks of the next research stage. Radio communication is maintained with the stations and all the commands given are accurately carried out. The stations have solar and stellar orientation and are working well.

The Mars-2 and Mars-3 in Flight

"Pravda", February 19, 1972.

The Long-Range Space Communication Center, 18. (TASS). The work of the Soviet automatic Mars satellites in near-planetary orbits continues. On February 18 the Mars-2 had completed 111

and the Mars-3 six revolutions around the planet. Radio communication is held regularly with the stations. In spite of the fact that, at the present time, the distance between the earth and Mars has increased to 244 million kilometers, communication with the automatic stations is reliable. Trajectory measurement is carried out during the radio communication sessions, telemetering information on the work of the on-board systems is received, as is scientific information obtained by the research equipment in the stations.

From January 22 to February 18, 1972 the Mars-2 and Mars-3 space vehicles continued measuring the temperature of the surface and the subsurface layer of the planet, studied its relief and determined the characteristics of the atmosphere of Mars and near-planetary outer space.

Information obtained at this time shows that the dust storm has ended, the temperature of the surface has increased to a level expected when the atmosphere is highly transmittent, and the contrast of details of the surface has increased in the red and near infrared regions of the spectrum.

Measurement of brightness of the temperature showed that the temperature at the depth of several tens of centimeters from the surface has practically no bearing on the time of day. The latitudinal distribution of temperature brightness shows that seasonal changes of temperature at this depth are significantly reduced in comparison with the surface temperature. This indicates the low /162 heat conductivity of Martian soil.

When the artificial satellite went behind the planet experiments were conducted into its atmosphere by using radio wave transillumination. The processing of signals obtained on earth determined the dependence of pressure on altitude in the atmosphere of Mars. It was shown that the pressure near the planet's surface, in areas where measurement had been made, was in the ranges from 4-8 millibars.

The boundaries of Mars' ionosphere were determined. Its lower boundary is at an altitude of 80-110 km. With an increase in altitude the electron concentration increases sharply, and then gradually decreases.

Measurement of ultraviolet radiation, scattered in the upper atmosphere of Mars, made it possible to determine the dependence of intensity of lines of atomic hydrogen and oxygen on altitude, and radiation in a line of hydrogen was recorded up to altitudes of approximately 2,000 km, where it exceeds the background level of the interplanetary medium. Radiation in the atomic oxygen line was traced to altitudes of approximately 800 km. Measurements made determined the dependence of the concentration of hydrogen and oxygen atoms on the altitude above the surface of Mars.

The artificial Mars satellites are continuing their scientific research.

Three Months in Orbit

"Pravda", March 2, 1972.

The Long-Range Communication Center, 1. (TASS). The Soviet Mars-2 and Mars-3 automatic stations are continuing their flight. On March 1 the Mars-2 completed 127, and the Mars-3 seven revolutions around Mars. From February 18 to March 1, Mars had moved another 15 million kilometers away from earth, and at the present time, the distance between the planets is 259 million kilometers.

Reliable, regular communication sessions are held with the Soviet artificial satellite.

Research into the surface and atmosphere of Mars in continuing from near-planetary orbit. Photographs are being taken. The nature of outer space surrounding the planet is being studied.

The Soviet automatic vehicles have been near the planet for three months, during which time much valuable, scientific information has been obtained on Mars and on near-planetary outer space.

The proposed work program for the Mars 2 and Mars-3 artificial satellites orbiting the planet is nearing completion.

A Plasma Experiment in Mars Orbit

("Novosti" Press Agency)

"Moskovskaya pravda", March 11, 1972.

The Soviet Mars-2 and Mars-3 automatic stations have been carrying out observations for three months in an orbit around Mars. Their instruments have investigated the planet and surrounding

space. Scientists are analyzing the information obtained, summing up the results and compiling a program for further experiments.

A correspondent of the "Novosti" Press Agency asked Oleg Vaysberg, a Candidate of Physical and Mathematical Sciences, and a section head at the Space Research Institute of the Academy of Sciences of the USSR, to tell us of work of instruments designed for studying charged particle fluxes, including one of the most /163
interesting space phenomena -- solar wind, and of some results obtained so far.

"To understand the mechanism for generating and accelerating solar wind particles is to solve one of the main problems of solar physics: this is to understand how the corona is heated to such high temperatures.

To some extent, solar wind is a natural laboratory, where physicists can study processes occurring in extremely rarified plasma, that is, in conditions which, in many respects, cannot be reproduced on earth. In this experiment, we were more interested in another question: the solar wind which flows around Mars.

The fact is that the flow of solar wind around earth, when the plasma flow interacts with the magnetic field of earth, has been studied sufficiently. Since solar wind has a supersonic speed, and the obstacle itself, the magnetosphere, has relative conductance, it influences the flow, and a shock wave is formed. A transition region forms between the shock wave and the magnetosphere. A plasma flow, heated as a result of colliding with the magnetosphere, flows around the magnetic field. Its external area is deformed,

forming the earth's magnetic tail, rather similar to the tail of a comet. Changes in solar wind cause magnetic storms on earth, polar auroras and ionospheric disturbances.

A second variation of this flow, which has also been studied well, is the interaction of solar wind with the moon. The moon is an obstacle of a completely different type. It has no conductance and, therefore, does not give a reverse reaction -- does not influence the flow of plasma. Solar wind directly interacts with its surface. Although a considerable amount of the flow is neutralized, a shock wave does not occur. Only a cavity is formed with a small concentration of particles, which the moon "selects" in the flow of solar wind: the so-called "corpuscular shadow".

Finally, the third class of interaction will take place when the solar wind flows around planets having an atmosphere, but not having their own magnetic field. Since the ionosphere of any planet has conductance, it must be expected that the progress of the phenomena, to a certain extent, must be similar to the process of solar wind flowing around the earth's magnetosphere, but only in the sense of the general characteristics of the flow-around zone. A magnetized flow of plasma will induce -- cause an electric current on the boundary of the ionosphere. A magnetic field of this current is also an obstacle for an oncoming solar wind.

During the flight of Mariner-4, American scientists detected some features of an interplanetary field around Mars, which they interpreted as a shock wave when solar wind struck the planet.

However, later calculations showed that this effect was more likely to be linked with the change of the magnetic field with time.

The Mars-2 and Mars-3 are investigating solar wind by using equipment which, in particular, will determine its speed, temperature and composition of the basic components. The measurements were done during the flight to Mars. For the first time, it was possible to obtain information on the characteristics of the geomagnetic tail at distances of 20 million kilometers from earth. However, as I have already said, we are more interested in studying particle fluxes in the direct vicinity of Mars. It can be confidently said that solar wind "meeting" the planet's upper atmosphere, must have a great effect on its structure.

Equipment on board the stations included an ion and electron /164
spectrometer. This equipment measures the spectral distribution of particles in an energy range from 30 electron volts to 10,000 electron volts. It is convenient to measure the parameters of the ion components of plasma, since ions give us the basic information on the hydrodynamic characteristics of the flow -- its speed and temperature.

During the first few days of the flight of the stations in orbit around Mars, we were able to pinpoint very sharp changes in the ion composition in the direct vicinity of the planet. The station's equipment registered low-energy ions in the order of hundreds of electron volts. Normally, such particles are not seen in solar wind.

Measurement has been carried out during six revolutions around the planet by the Mars-3. It showed that regularly, when the station approaches the planet, it enters a low-energy particle zone. The nature and the suddenness of the change of ion composition, and also the sudden changes in velocity of particle flow, which was observed at that time, gives basis to suppose that apparently, we are dealing with a shock wave.

Of course, this is only a preliminary conclusion, and has not been validated. For example, when we attempted to determine the shape of the boundary where the sudden change of velocity occurs, it appeared that the curve obtained approximately coincided with the theoretically calculated shape of the shock wave. Further study of the flow-around zone, comparison of results of recording the parameters of plasma flow before and after the shock wave, and analysis of magnetic measurement will allow us to make final conclusions. It is possible that new information will be obtained on the characteristics of the upper ionosphere of Mars.

Mars before and after a Storm

Professor V. Moroz, Doctor of Physical and Mathematical Sciences,
L. Ksanfomaliti, Candidate of Physical and Mathematical Sciences

"Izvestiya", March 21, 1972

The fourth month of work near Mars is being completed by the Mars-2 and Mars-3 interplanetary stations. The first anxious days are over, that unforgettable communication session when the first paper tapes with their complex, curved shape fell on our table

-- the telemetering recordings of instrument readings. The time has arrived for painstaking processing, the analysis of measurement and preparation of the first scientific publication. Conclusions can be made showing that the study of the material obtained is still far from complete.

As was reported, our artificial Mars satellites are equipped with two sets of equipment, one of which we can call arbitrarily an astrophysical one, the other (still more arbitrarily) a geophysical one. The first consists of instruments designed for investigating the atmosphere and the surface of Mars according to its radiation in different spectral regions, and was produced, mainly, by astrophysicists. The second is for investigating the interplanetary medium and vicinity of Mars, and was produced by geophysicists. Experiments conducted with these two sets of instruments, -- are the basic ones in our station's program, and photography of the planet plays an auxiliary role. This is the main difference between ours and the American program for the Mariner-9 artificial satellite, the main aim of which is television photography of the planet.

We shall give the results of experiments carried out at the laboratory of infrared astronomy at the Space Research Institute of the Academy of Sciences of the USSR, in conjunction with the State Astronomical Institute im. Shternberg, and many other scientific and industrial organizations.

These experiments studied the radiation of the planet, to be more precise, small areas of it, near a certain line ("measurement /165

path') in different sections of a wide range of wavelengths -- from 0.36-40 μm. The human eye reacts to radiation in a relatively narrow interval from 0.4-0.7 μm, the wavelength here changes less than twice. Scientific instruments "saw" wavelengths differing a hundred times.

The field of vision of all these instruments is from 0.25-1° and when approaching close to the planet -- in the pericenter receive radiation of sections measuring from 6-25 km. From earth, during astrophysical research into Mars, one normally isolates areas measuring not less than 500 km. Apart from this, research into the night side of Mars is practically impossible.

Clouds in the atmosphere of Mars are rare. Unlike Venus, where the atmosphere is 10,000 times more powerful and a dense cloud layer completely obscures the surface. When the Mariner-9 and later the Mars-2 and Mars-3 went into orbit it seemed as if they had discovered some new, unknown planet. Mars was shrouded with a cloud layer, almost as impenetrable as that of Venus. It was impossible to distinguish the dark regions from the light, and photography of the surface was practically impossible.

What had happened on Mars? Observers already know that during major oppositions, the planet's disc for some weeks is covered by a light veil, behind which the dark Martian regions ("seas") become hardly distinguishable. The brightness and color of this veil is almost the same as in the bright regions of Mars -- "continents". The continents are covered with a layer of finely-crushed material, dust. Apparently, there is dust on the surfaces

of che maria, but it is coarser, and there, probably, there are greater rock extensions. It is suggested that during a dust storm a fine, "continental" dust rises into the atmosphere and extends over the whole planet.

Such a dust storm began during the first ten days of October and lasted three months. During the present opposition, the dust storm was especially long. It hindered photography, but measurement, carried out by our astrophysical instruments, gave much new information on the dust storm itself. In December and the beginning of January, measurement was made when the atmosphere contained dust. In February all signs of dust disappeared.

The Mars-3 carried out three series of measurements during the storm and four after it. A comparison of them was extremely useful. During measurements on December 27 and February 16, the measurement paths passed over the Mare Iapigya. Whereas on December 27 the Iapigya was discernible on a wavelength of 1.4 μm, and not seen at all on a wavelength of 0.7 μm, on February 16 Iapigya was half as bright as the neighboring continents in both wavelengths. The difference in contrast in the two wavelengths between the continents and the maria during the storm allows us to estimate the size of dust particles, and the change of contrast between February 15 and 16 in one and the same region -- the thickness of the dust cloud.

According to a preliminary estimation, the average radius of particles on December 15 over the Iapigya region was rather less than a micron, and their number over 1 cm^2 was approximately

100 million. If clouds of such density cover the whole planet uniformly, then its atmosphere must contain several billion tons of dust. These estimations suggest that particles, basically, are of a silicate composition, which agrees with infrared spectra obtained by the Mariner-9.

Particles of such small dimensions, even in the very rarified Martian atmosphere, fall very slowly -- approximately a month even without supporting vertical motion in the atmosphere. It follows /166 that during the investigation period there was no prolonged dust storm, in the true sense of the word, that is, constant wind. Winds which raise dust from the surface only occur in the initial phase of the phenomenon, then the dust is suspended for a long time in the calm atmosphere.

Hence, a dust storm consists of the formation of a cloud layer in the planet's atmosphere, but as opposed to Venus, it is temporary and not constant. What is the altitude of this layer? The first indications were provided by ground observations carried out by one of the authors in October 1971, during the initial phase of the dust storm. It seems that belts of carbon dioxide were considerably reduced when the dust storm began. This means that the upper cloud boundary is extremely high, not lower than 8-10 km.

The whole of Mars' spectrum was observed from earth averaged along its disc. The Mars-3 obtained similar observations for individual regions of Mars. It appears that the altitude of clouds is not identical, above high regions they are lower, and above low

regions higher: during the dust storm, the Mariner-9 photographed some high regions protruding above the cloud level.

On Venus the atmosphere and cloud layer are more transmissive to solar radiation than to thermal radiation of the surface. As a result, there is a "greenhouse effect" -- the surface heats up significantly. Does the same happen on Mars during a dust storm? Apparently quite the reverse occurs. The cloud layer with the characteristics shown above allows thermal radiation of the surface to pass through better than short-wave, solar radiation. Therefore, the surface does not heat up but cools. One might say there is an "anti-greenhouse effect". Since Martian clouds are practically transmissive in a radiometers sensitive infrared band, it "sees" the surface through the clouds and measures its temperature. During the dust storm the surface temperature fell by 20-30° in comparison with that which was expected from normal conditions (without dust clouds). When the storm ended, the temperature rose. During the dust storm the surface was cooled, and the atmosphere itself heated up, since it absorbed a considerable amount of solar radiation.

There was a very small content of water vapor in the atmosphere during the dust storm and after it. It did not exceed 5 μm of precipitated water -- 2,000 times less than in the earth's atmosphere. From previous ground observations we know that the content of water vapor in the Martian atmosphere fluctuates considerably. Sometimes it reaches 50 μm of precipitated water, sometimes less than 10 μm -- this is the instrument limit of ground observations.

It is difficult to say whether the small amount of humidity in the Martian atmosphere during the dust storm and after it was a coincidence, or whether there is some connection. The existence of water on Mars is an extremely interesting problem.

In one of the final photographs taken by the Mariner-9 there is a formation similar to the channel of a dried-up river. We know that water in liquid form cannot exist on Mars: it either freezes or boils (due to the low atmospheric pressure). Such channels indicate that until relatively recently the climate on Mars could have been completely different -- the temperature and pressure were higher. It could be that these enormous climatic changes are of a periodic nature.

A Radio Telescope in Orbit around Mars

N. Krupenio, Candidate of Physical and Mathematical Sciences ("Novosti" Press Agency)

"Moskovskaya pravda", June 8, 1972.

Artificial Mars satellites -- the Mars-2 and Mars-3 Soviet automatic interplanetary stations -- were equipped with many scientific instruments designed for investigating the planet's atmosphere and surface. They included a miniature radio telescope working on a wavelength of 3.4 cm. This is the third time that a radio telescope has been fitted into a space vehicle. As opposed to its two "older brothers", which measured the intensity of radio-frequency radiation of the earth and Venus, the Mars-3 radio telescope is much more "intelligent". It not only measured the /167

intensity but the polarization of the planet's radio-frequency radiation. The simultaneous measurement of the intensity and polarization of Mars' radio-frequency radiation made the processing of the radioastronomical experiment more difficult. However, the results justified these difficulties. Only the most complex research could determine the temperature of the planet's surface layer to a depth of approximately 0.5 m. Apart from the thermodynamic temperature by using polarization measurement, the dielectric permeability of matter of Mars' upper cover, several tens of centimeters thick, was determined.

The on-board radio telescope worked with a fixed anetnna system with a diameter of approximately 60 cm. The surface of the planet was scanned by the radio telescope when the Mars-3 artificial satellite moved in its orbit. At the same time, the radio telescope received the radio-frequency radiation from a section of the surface, the linear measurement of which was approximately 200 km. It is worth mentioning that the best ground telescopes can only measure radio-frequency radiation of the planet as a whole and not in detail. In order for a ground radio telescope to detail radio-frequency radiation of Mars to the same degree as the on-board Mars-3 radio telescope, it would need an antenna diameter of more than 30 km. The largest radio telescope being built on earth will have a rotating antenna with a diameter of 100 m. The antenna size and accuracy required for measurement of Mars is a dream which cannot be realized in the near future.

The Mars-3 interplanetary station has an elongated orbit. Its minimum distance from the planet's surface (pericenter) is approximately 1,500 km, the maximum approximately 200,000 km, and the orbital period around the planet is approximately 12 days. The orbit was oriented relative to the surface of Mars so that the radio telescope can receive in sequence during each revolution the radio-frequency radiation of the surface from 60° south latitude to 30° north latitude.

The northern latitudes of Mars have been studied very little. Whereas we have information of radiation observations from earth for the area of the northern hemisphere from 3-22°, by which we can estimate the dielectric permeability of matter on the upper cover, the southern hemisphere is a completely white spot. Temperature information on the planet's subsurface layer in specific regions of the southern hemisphere, obtained by the Mars-3 radio telescope, strictly speaking, will have nothing with which to be compared.

The results of the radioastronomical experiment were very interesting. The theoretical calculations were confirmed, according to which there are never positive temperatures at a depth of 0.5 m, where the cold is lower than -40° C. When moving towards regions in the southern latitudes, towards the 60th parallel, the temperature at this depth falls even more by approximately 30°. It was found that the temperature at a depth of 0.5 m at a certain point did not depend on the time of day. The heat conductivity of Martian soil varies in different regions. /168

Processing of polarization measurement of radio-frequency radiation showed that the density of matter of the upper cover varied for different regions of the southern hemisphere.

The small dark region, Cerberus, was very interesting. It was examined by the Mars-3 at night. The radio telescope recorded an increase in the dielectric permeability in this region. An increase in the dielectric permeability and night temperature of the surface are caused by denser soil. Processing of the radio-astronomical experiment completely confirms this. Whereas in nearby regions the density of the upper cover is approximately 1.2 g/cm^3, in the Cerberus region it is twice as great.

Since the radio telescope transmitted information from an area with a diameter of approximately 200 km, this increase in density can indicate rock on the surface in that region (with a density of approximately 3.5 g/cm^3).

Processing of information collected by the on-board radio telescope, apparently, will give additional knowledge on thermal conditions and the electrical properties of substance of Mars' upper cover and, probably, determine in what way the dark and bright regions of the planet differ from each other.

Mars, Far and Near

B. Kozlov, Candidate of Technical Sciences

"Radio", No. 7, 1972.

Mars, one of the closest planets to earth, has always been of special interest to scientists who believed that life could possibly exist there.

The problem of whether life exists on another planet is not only interesting in itself. Its solution is extremely important for science. By discovering life on another planet, studying the was in which it originated, its form of development, etc., scientists would understand better the origin and evolution of life on earth.

Successes in the development of technology have meant sending to Mars automatic interplanetary stations with scientific equipment for directly measuring and observing, checking theories and attempting to answer the question on whether life exists there.

The flights of automatic stations to Mars have provided several surprises. For example, no one expected that the relief of the terrain shown on photographs would be so similar to that on the moon. One can now say that the atmosphere of Mars almost completely consists of carbon dioxide, and the temperature near the surface is 5-10 millibars, which corresponds to a pressure in the earth's atmosphere at an altitude of approximately 30-40 km. The temperature in the equatorial zone at noon is 15-20° C, whereas near the poles it can fall to 130-150° of frost.

It is possible that the surface of Mars is covered with sand. Strong winds blow away dust from one place to another, and dust storms occur. It was noticed that they reached their greatest intensity during oppositions. According to present information, an exceptionally strong storm occurred during the last quarter of 1971.

Radar observations show that on Mars the maximum difference in elevation is 12 km, with average inclination values of approximately 3-4°. A layer of permafrost begins at a depth of approximately 50 cm, where the temperature hardly changes during the year and is from -50 to -70° C. Apparently, polar caps observed on photographs consist of dry ice crystals (solid carbon dioxide) and dust. In summer, the southern cap normally melts completely, and the northern one is reduced but does not disappear completely. Martian clouds were observed through telescopes near the poles. Scientists believe that they are a mixture of dry ice crystals, ordinary ice and dust. /169

It can be seen that conditions on Mars are quite severe, but not so as to completely exclude the possibility of the existence of life on the planet (microorganisms or even plants).

It seems a simple task to send an automatic control unit to Mars which, with its scientific equipment, would determine whether life existed or not. In fact, this is a very complex problem. There are many obstacles and they often occur in most unexpected spheres. For example, it appears that it is quite difficult to produce a "life detector" -- an instrument for detecting life on

Mars. It would be difficult to detect living organisms (if they exist) by their external appearance, since they could be different from those on earth. One must find other signs which are more reliable. Where and how can we look for them?

Is it possible to look for a certain structure or rely on the presence of biochemical processes? Firstly, this requires the use of complicated equipment, and secondly it is not quite clear which signs of life can be accepted as a base. The fact is that in inanimate nature there are many analogues of biochemical processes, and if they are examined in isolation, they can confuse the researcher. For example, an analogue in metabolism in inanimate nature are the varied oxidation-reduction processes, and cell division often makes it difficult to distinguish between some processes in crystals.

These are not all the problems which must be solved in order to find the correct answer. We need extensive information, the more extensive, the more chance of success.

Therefore, science is attempting to study in more detail space around Mars, the gas composition, temperature, pressure and other characteristics of the atmosphere, and to obtain, if possible, more detailed and complete maps and pictures of its surface, etc. Having this data, one can attempt to say where to look for life and in what form it might exist. Since individual experiments do not give a definite answer on whether life exists, one must conduct a whole range of different experiments. By comparing and generalizing these results, one can put more faith in their reliability.

What is the overall plan for such an extensive space experiment?

A large space vehicle when approaching Mars goes into artificial satellite orbit of the planet (MAS). After this the descent vehicle (DV) is separated, and makes a soft landing in the selected area. The DV has a scientific base-laboratory and a self-propelled device, a Mars vehicle, also equipped with scientific instruments and, of course, radio transmitters for communication with the base and the Mars satellite. The Mars vehicle will study the surface of the planet in a radius of 300-500 km for 3-6 months, and afterwards return to the base. It will carry out the majority of physiochemical and biological experiments. If there are complications or if it finds something interesting, it will take samples. During investigations it will systematically take photographic images of /170 the area, and the film will be stored and sent back to earth together with the samples.

Meanwhile, the base station will carefully study the landing area and carry out research requiring more time. The results are periodically transmitted to the Mars satellite, and from there back to earth.

The Mars satellite studies space near Mars, photographs the surface of the planet and works as a relay on the radio link between Mars and earth. When the experiments end on the surface of Mars, part of the base station with soil samples collected by the Mars vehicle, and photographic and magnetic film, flies off, docks with the satellite and returns to earth.

This is only a general picture of one of the possible variations of a flight to Mars. It must be noted that in the first part it resembles the space flight of Soviet Mars-2 and Mars-3 space vehicles, and also the experiment when a descent vehicle made a soft landing on the planet's surface. This flight gave science valuable information which, of course, can be successfully used for future Mars research.

Let us try in more detail to show the flight schedule of which we spoke earlier. It must be stressed that it will last approximately 2-2.5 years and will require the use of various technical aids which have been developed, based on new achievements in science and technology. The most important of these are radio engineering, electronics, television, cybernetics and communications.

When carrying out a space flight such as this, we shall have to solve many unusual problems. For example, the space communication links between the earth and the Mars satellite or the earth and the Mars vehicle. We shall reckon that the distance between the two extreme points of the route, on an average, will be 200-300 million kilometers. Taking into account that radio waves are propagated with a speed of approximately 300,000 km/sec, the time for a signal to pass to both ends is 24-35 min. Obviously, this must be allowed for when controlling the space vehicle's systems, since it moved towards Mars at great speed. Further difficulties await us when organizing communication with the scientific station on planet's surface or with the Mars vehicle.

Imagine that we have decided to maintain communication with the Mars vehicle directly, and not via the satellite operating as a relay. If one takes into account that communication between space objects is only possible when there is direct visibility, a radio link of this type will give very poor results. There will be few sessions -- once or twice a day (since the rotation period of Mars around its axis is approximately 25 hours), and they will only last a few minutes. Let us add that it is difficult and unsuitable to install large antennas on the Mars vehicle: they must not only be set down on the planet but must be continually directed toward earth which is observing it. There is also the additional weight and energy expenditure, new instruments and equipment. It is better to keep the large antenna in the Mars satellite, since this must maintain communication with earth. This will make it possible to reduce the size and weight of the antenna on the Mars vehicle and broaden its directional patterns in order to keep track of the satellite.

How can this complex scientific program be accomplished? The instruments must be controlled, and the need for setting up new experiments will be determined by the results of previous ones. Must one wait for the next communication session with earth? Obviously, cybernetic facilities and special computers must be set /171 up to control the progress of scientific research, decide independently what to do and when, evaluate the results obtained and, depending on these, decide and determine the further course of the experiment and the work of the vehicle's systems.

A cybernetic automatic control unit such as this must also be used for controlling the movement of the Mars vehicle. Its tasks are as follows. The terminal point and overall direction of movement can be chosen on earth and it is impossible to forecast accurately a concrete path and the vehicle's behavior in it. Obstacles will appear in its path: stone, craters and, perhaps, caverns or cliffs. They must be "seen", avoided, and a path chosen which is safe, and if there is something in its path it must approached and "examined" to see what it is. Depending on the result of the examination, it either continues moving, investigates the object in detail, or takes a sample with it for further study at the base or on earth. These problems must be solved by using special, independent control complexes.

The Mars vehicle can be equipped with an irradiator using an optical system which illuminates the area tens of meters ahead of it with a vertical beam. The beam travels over the selected area of the ground in front of the vehicle in sequence. It must move in such a way that the surface investigated, when viewed from above, forms a scanning field, the lines of which are in a fan shape and are intersected at a point where the irradiator is placed. The thickness of the beam and the distance between the lines determines its resolving power (Figs. 29, 30).

Television cameras, forming a stereo system, are placed at both ends of the irradiator. These are the two eyes of the vehicle, positioned so that they only see the illuminated points through special light filters. Video signals from both "eyes" are

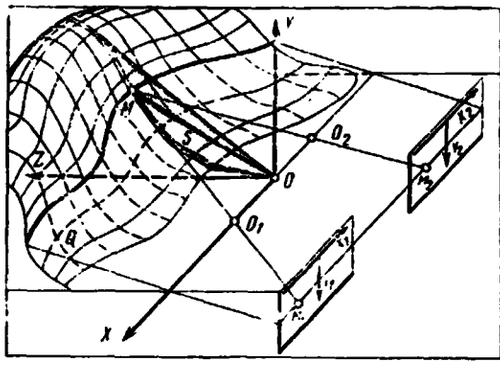

Fig. 29. The measurement of characteristics of the relief of the terrain in front of a self-propelled vehicle. XYZ - The coordinate system of the terrain; (M)XYZ - A certain point on the terrain; Q - The scanning [rotating around axis (OY)] plane; S - A light beam from the irradiator, at point O; $M_1(X_1, Y_1)$, $M_2(X_2, Y_2)$ - Images of points M on the left and right screens of a stereo pair.

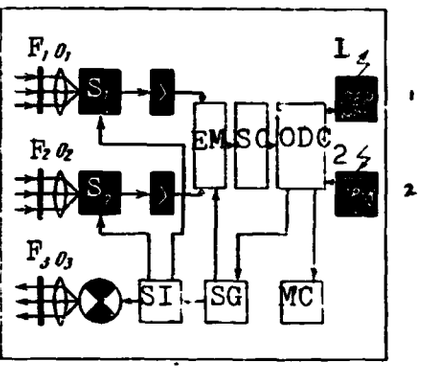

Fig. 30. A functional diagram of an autonomous movement control system. F_1, F_2, F_3 - Light filters; O_1, O_2, O_3 - Optical objectives; S_1, S_2 - Television sensors; EM - An electronic measurer for coordinate points; SC - A signal conditioning unit; ODC - An on-board digital computer; SG - A synchronous generator; SI - A scanning irradiator; M.C. - Movement control. 1 - Transmitter; 2 - Receiver.

processed by the on-board digital computer. As a result, complete data on the relief of the terrain appears in the machine. The basic technical characteristics of the terrain trafficability of the Mars vehicle are known earlier, and the vehicle, knowing these, sets a course along which it must travel. If, for some reason, an emergency occurs (or may occur in the near future), a computer switches off the engines and during the next communication session will transmit a description of the situation to earth and await further instructions. /172

There are other reasons for using computer equipment when studying planets in the solar system. We have already said that

scientific experiments in themselves are varied, numerous and very complex. As a result, when carrying them out much information will be obtained which must be transmitted to earth. This is where another difficulty arises. For example, if we equip a Mars satellite with the same transmitting equipment as an earth satellite, owing to the great distance, the transmission speed will have to be reduced by approximately 100 billion times. Otherwise, the signal will not be recognized among the background noise. Of course, the special Long-Range Space Communication Center is developing special transmitters and increasing their power. But this cannot completely solve the problem, and there is only one solution -- process the results obtained before transmission, select from them that which is valuable or new, and disregard what is not required. Specialists call this the compression of information. Here is an example.

Suppose we have to transmit information on changes of temperature inside the Mars vehicle. It can be simply measured from time to time (every 5-10 min), recorded on a tape recorder and later transmitted. Here, almost all the figures will be identical and the time for their transmission will have practically no value. This can be done another way: an additional electronic unit can be installed which automatically shows whether there are great variations in the information and whether any critical values have been reached. In this case, the effectiveness of the transmission is greatly increased.

A similar device, produced at the Space Research Institute of the Academy of Sciences of the USSR, was installed in the Soviet Mars-3. It processed information obtained from a French instrument, measuring ultraviolet frequency radiation of the Sun, and reduced the amount of information transmitted by approximately 100 times.

This picture seems rather fantastic. But people once dreamt of earth satellites. There is no doubt that in the near future we shall see new, amazing space experiments.

A TASS Report: The Program Has Been Accomplished

"Pravda", August 23, 1972.

The preplanned complex research program of Mars, carried out by the Soviet Mars-2 and Mars-3 automatic stations in orbit around it, has ended.

A great deal of scientific information on the physical properties of the surface and atmosphere of the planet and outer space near it has been obtained.

The Mars-2 and Mars-3 automatic interplanetary stations were sent into a flight path to Mars on May 19 and 28, 1971, respectively. During the flight from the earth to Mars, lasting more than six months, the stations regularly transmitted scientific /173
measurement on the physical characteristics of interplanetary space.

On November 27 and December 2, respectively, the Mars-2 and Mars-3 were sent into near-planetary orbit and began to study the planet and space directly surrounding it.

An outstanding achievement during this space experiment was the first soft landing of a descent vehicle from the Mars-3 on the planet and the transmission of a radio signal from its surface to earth. Pennants showing the State Emblem were left on the surface of Mars.

To date, the Mars-2 has completed 362 revolutions, and the Mars-3 20 revolutions around the planet.

For more than eight months the stations orbited Mars and conducted complex research into the properties of the surface and atmosphere by the nature of radiation in the visible, infrared and ultraviolet ranges of the spectrum, and also in the radio wave band.

This measurement showed the temperature of the surface of the subsurface layer, and traced its changes depending on the aerographical latitude and the time of Martian days. Some thermal anomalies were detected on the planet's surface. High-altitude profiles of the Martian surface along the satellite's path were obtained by information on the absorption of infrared radiation by carbon dioxide.

Measurement of the water vapor content in various regions of the planet showed that during the observation period it was approximately 5,000 times less than in the earth's atmosphere.

Measurement of scattered ultraviolet radiation provided information on the structure of the planet's upper atmosphere -- its extent, composition and temperature. Study of the refraction of radio waves when they passed through the atmosphere of Mars made

it possible to determine the pressure and temperature near its surface.

Changes in the transmittance of the Martian atmosphere during an unusually strong dust storm which occurred during the first two months of the station's flight, gave information on the characteristics of this interesting phenomenon, and an evaluation was made on the content and average dust particle size in the planet's atmosphere.

The dust storm hindered photography of the planet and some scientific measurements. However, pictures of Mars' disc, taken by photographic equipment on board the stations, gave useful scientific information on the planet. Photographs were taken of Mars for the first time in phases not observed from earth. Photographs transmitted from the stations added to the information on the surface, the structure of the atmosphere and the planet's shape.

The flight program of the Mars-2 and Mars-3, which had quite different orbits, devoted much attention to the direct measurement of characteristics of fields and particles of different energies in space surrounding Mars.

Measurements made by the satellites enabled studies to be made on the question of the existence of a magnetic field near the planet. Research into the regularity of a magnetic field is extremely important for understanding not only the nature of Mars, but the origin and evolution of planets in the solar system.

Measurements made by the "Stereo" equipment, developed and produced by French specialists in accordance with the Soviet-French

program of cooperation into the research of outer space for friendly purposes, obtained additional information on the structure of the Sun's radio-frequency radiation.

Another stage has been completed in outer space research.

Scientific establishments in the Soviet Union are continuing /174 to process and analyze information obtained by the Mars satellites.

The results of this new space experiment will give science valuable information on the nature of planets in the solar system.

The outstanding success of Soviet astronautics opens new possibilities for conducting systematic, scientific research into heavenly bodies by using automatic vehicles.

Soviet Automatic Control Units Investigate Mars

(TASS)

"Pravda", August 25, 1972.

Soviet Mars-2 and Mars-3 automatic interplanetary stations, which became Mars satellites more than eight months ago, have completed their scientific research program. Their instruments carried out observations which told us many new things about the "red" planet. The complete processing of information obtained and analysis will still take some time, but the first results can be given. The American Mariner-9 satellite carried out measurement simultaneously with our stations.

The Soviet and American space vehicles were sent into orbit around Mars and were equipped with mutually supplementing sets of

scientific instruments; they can operate for long periods and information can be exchanged between Soviet and American scientists while experiments are still being conducted, which is extremely useful when studying Mars.

The Mars-2 and Mars-3 orbital stations were sent into quite different orbits around Mars, which was dictated by research tasks both of the planet itself and the characteristics of space surrounding it. Both stations approached Mars to a minimum distance of approximately 1,500 km; the maximum distance of the Mars-2 station was more than 25,000 km, and that of the Mars-3 more than 200,000 km.

When the Mars-2 approached Mars a capsule with a pennant carrying the image of the emblem of the Soviet Union was dropped onto the planet.

The descent vehicle of the Mars-3 made a soft landing between the Electris and Phaethontis regions. Television signals from its panoramic cameras were received at the estimated time simultaneously on two individual channels; the level of the signal was high, without interference, however, the transmission of signals soon stopped. No significant contrast details were shown in the panorama transmitted at this time. The reason why the transmission stopped so suddenly was not clear. Probably it is linked with local features of the landing area, which are completely unknown, or with the strong dust storm occurring on the planet at the time.

It is possible that the dust storm covered details of the surface with a "veil" when that part of the panorama was photographed.

The study of materials of this complex experiment continues. The successful soft landing on the surface of Mars opens up new possibilities for researching this planet by direct methods in the near future.

The Soviet Mars satellites carried out 11 scientific experiments. Seven studied the planet itself; three measured the parameters of the interplanetary medium; and one, carried out in conjunction with French scientists, investigated the Sun's radio-frequency radiation.

During their flight to Mars, the Mars-2 and Mars-3 stations regularly measured the flow and energy of solar plasma, and also /175
the parameters of interplanetary magnetic fields. Electron concentration in the interplanetary medium was determined by the nature of radio wave propagation in two coherent frequencies. The Mars-3 station conducted the joint Soviet-French "Stereo" experiment and investigated the three-dimensional structure, directivity and mechanism of solar radiation.

Measurement of ion components of plasma during the flight showed that disturbance of interplanetary plasma, occurring when it interacts with the earth's magnetic field, was observed in a direction away from the Sun at distances of up to 20 million kilometers. In the plasma disturbance zone, caused by a flow of "solar wind", both components of plasma -- electrons and ions -- underwent almost periodical fluctuations of velocity. As Mars was approached, when the distance from the Sun was significantly increased, there was a simultaneous reduction in electron concentration in the

interplanetary medium. The electron temperature near Mars was several times less than near the earth. Numerous measurements using magnetometers showed that the value of the interplanetary magnetic field, on an average, was in ranges of 5-6 gammas (1 gamma = 10^{-5} oersteds; the earth's magnetic intensity is approximately 0.4 oersteds).

Of course, the most important information was on the planet itself and this is why vehicles were sent to Mars. Measurement of its temperature surface and soil were made, its relief, composition and atmospheric structure were examined. Scientists could observe Mars closely and for a long period for the first time.

The field of vision of instruments on board the stations covered areas of the surface measuring from 6-50 km. From earth, similar observations using optical telescopes distinguished areas with dimensions of 500-1,000 km and ground telescopes receive radiation from the whole disc at once. This is why Mars satellites investigate the planet in more detail than is possible from earth.

Almost all the station's instruments were oriented so that when passing through the pericenter (the minimum distance from the center) they "looked at" the planet. At this time, the satellite was moving at a speed of approximately 4 km/sec, and the instruments examined the surface of Mars from edge to edge in approximately half an hour.

An infrared radiometer, receiving radiation from the planet in a wavelength range of 3-40 μm, measured the temperature surface along the satellite's path. This is a kind of remote thermometer.

The paths began in the southern hemisphere, where at that time, the Martian summer was ending, crossed the equator and ended in the northern hemisphere. The initial points of the paths were in an area where it was still morning, and the final ones where it was afternoon, evening and sometimes nighttime. Therefore, the temperature along these paths varied widely: from +13° C (for 14 hours local solar time of the 11th degree south latitude) to -93° (local time 19 hours, 19th degree north latitude). In the area of the northern polar cap, the temperature dropped even lower -- to -110° C.

It is interesting to know the temperature on the surface of Mars in various latitudes at a different time, firstly, because it is one of the main climatic characteristics, and secondly, one can judge the type of material, of which the soil consists, by the changes of temperature during the day and from place to place.

In February, the measurement paths of the Mars-3 ended near the northern polar cap. An infrared radiometer showed here a temperature lower than -110°.

As opposed to the southern polar cap which disappears in summer, the northern cap exists throughtout the year and, possibly, the overall amount of solid carbon dioxide and frozen water in it considerably exceeds the amount of these substances in the gaseous atmosphere of Mars. /176

The on-baord radio telescope measured the intensity and polarization of radio-frequency radiation on a wavelength of 3.5 cm along the same path. As opposed to an infrared radiometer, measuring

the surface temperature, it gave the soil temperature at a depth of 30-50 cm. The temperature below the surface at a certain depth is not affected by daily fluctuations, and this indicates the great thermal lag and low heat conductivity of the soil.

Apart from temperature, the dielectric constant of the soil was also determined, the value of which depends mainly on its density. Measurements showed that changes of soil temperature and the dielectric constant are linked, that is, higher temperature values of different areas correspond to higher values of the dielectric constant. This shows that the soil density changed along the measurement path. Apparently, when there are large values of the dielectric constant, there is crushed soil.

An infrared photometer in the carbon-dioxide absorption band with a wavelength of 2.06 μm showed that there was a large amount of carbon dioxide in the vertical column of Mars' atmosphere at various points along the path. It determined the pressure near the surface, which varied in different regions, owing to their different altitudes above the mean surface level. On an average level, the pressure on Mars is equal to 5.5-6 millibars (approximately 4-4.5 mm Hg) which is approximately 200 times less than on earth. By knowing how the pressure varies along the path, the relative altitudes could be determined and the surface relief could be found.

Observations from earth detected altitude differences of up to 12-14 km in the equatorial region of Mars, extending over large

areas. Only more detailed study of the relief can be made from satellites.

For example, the path made by Mars-3 on February 16. At first, it passed over the Hellespontus region which is 2-3 km above the mean level. Then it reached the northeast edge of the bright region of Hellas, and here the relief falls sharply (to 1 km above the mean level). Then it rose sharply towards the dark regions of Iapigya and Syrtis Major, where the highest point is approximately 3 km above the average level. A high-altitude section shows a series of wide peaks and valleys in the dark regions. The height gradually decreases to the north of Syrtis Major. Height differences are greater in some regions.

A dust storm was raging over Mars when our stations went into orbit. For two months, the planet was covered by dense clouds of dust which had risen from the surface. Measurement, made by an infrared photometer in December, showed that these clouds were approximately 10 km above the mean surface level. The cloud layer was thinner above the higher regions and thicker above the lower ones.

Dust storms on Mars are a powerful and, as yet, enigmatic phenomenon. For a few days, the normally transmissive atmosphere of Mars becomes almost as radiopaque to visible radiation as the cloud atmosphere of Venus. But the transmittance increases, as photometry measurement showed, as the wavelength increases. This indicates a considerable amount of very fine dust particles of approximately 1 μm in the clouds. These particles settle very

slowly, and this agrees with the general length of a dust storm. On the other hand, photographs from the Mariner-9 show there was a rapid increase of transmittance at the end of December. It was not complete, but after ten days visibility significantly improved. /177 To explain this it must be assumed that in the clouds there is a certain proportion of particles, rather more than a tenth of a micron in size, which settle rapidly. A photometer repeatedly observed clouds visible in blue rays (a wavelength of 0.36 μm) and invisible in red rays (0.7 μm). These clouds must consist of particles much smaller than a micron.

Generally, particles of different size are contained in Martian clouds during a storm, and the ratio of them changes over time. These clouds cool the surface and increase the atmospheric temperature, which in fact was observed. A type of "anti-greenhouse effect" was created, opposite to the situation on Venus, where the atmosphere is heated due to infrared opacity of the atmosphere.

A photometer, designed for an absorption band of water vapor with a wavelength of 1.4 μm, showed that the content of water vapor during the whole research period did not exceed 5 μm of precipitated water -- thousands of times less than in the earth's atmos phere. Mars is a drier planet than expected: ground observations previously sometimes detected there up to 50 μm of precipitated water. Now, it is difficult to say if this dry period coincided with the dust storm or if there is some link between these events.

Two experiments conducted by the Mars-2 and Mars-3 were designed for investigating the upper atmosphere of Mars. An

ultraviolet photometer recorded solar radiation, scattered by hydrogen and oxygen atoms in the upper atmosphere of Mars at altitudes from 100 to several tens of thousands of kilometers. As opposed to the optical complex, all the instruments of which "looked" down, on the planet, the ultraviolet photometer was directed in the pericenter towards the "horizon", parallel to the surface of Mars. The instrument recorded radiation of atomic oxygen in three adjacent lines with a wavelength of 1,300 angstroms and a radiation of atomic hydrogen with a wavelength of 1,216 angstroms (an angstrom equals a 100 millionth part of a centimeter).

The density of scattered atoms and their temperature were calculated by observations of intensity in these lines. Near the surface of Mars, the atmosphere consists basically of carbon dioxide, however, at an altitude of approximately 100 km solar ultraviolet radiation breaks it down into a molecule of carbonic oxide and oxygen atoms. A similar process in water vapor creates hydrogen atoms which are 16 times lighter than oxygen atoms. This is why the atmosphere on Mars above 300-400 km becomes mainly atomic-hydrogenous. Traces of oxygen were registered on all orbital revolutions up to an altitude of 700-800 km, where its concentration was only 100 atmos/cm^2. The density of lighter hydrogen falls very slowly, decreasing from 10,000 atoms/cm^2 near the planet to 100 atoms and even less at a distance of 10,000 km. Measurement at these great distances was made during special sessions by the Mars-3.

The temperature of the upper atmosphere in the range of altitudes from 100-200 km increases, and above this remains constant.

Almost the same picture is true of upper atmospheres of the earth and Venus. The strange thing is that the upper atmosphere of Mars is more similar to that of Venus than earth.

A second experiment into investigating the atmosphere does not require a special instrument and is based on analyzing the signals of the stations' centimeter radio transmitter when the satellites go behind or emerge from behind Mars' disc. This is extremely important for investigating Mars' ionosphere which is 10 times less dense than that of the earth. The ionosphere on Mars is "pressed" to the surface: the maximum electron density is at an altitude of /178 140 km (for the earth this is 300 km). At altitudes of approximately 110 km a second maximum is observed, the electron concentration of which is approximately three times less. It is possible that at altitudes of 65-80 km there may be a third relative maximum, with an electron concentration of approximately 10,000 particles/cm^3.

The station had a set of three instruments designed for investigating the magnetic field and charged particles in the vicinity of Mars. In principle, this investigation may show the internal structure of Mars and, mainly, if the planet has a metallic core or not.

In 1965 the Mariner-4 did not detect a magnetic field near Mars. However, it flew at a distance of 9,100 km from the planet's surface. The Mars-2 and Mars-3 flew at a distance of only 1,500 km. Measurement of the magnetic field near the planet was done down to this distance by using a sensitive ferromagnetic probe magnetometer. Distinct changes in the magnetic field were observed which were

eight times greater than the level of the interplanetary background. The intensity of the field when approaching Mars increased according to all three components of the magnetometer. It is possible that Mars has its own weak, dipole magnetic field. However, additional analysis of measurement data is required to answer this question more reliably, which is so important for understanding the nature of the planet.

According to measurements done by the Mars-3 using electron traps, there was a uniform increase in the flow of electrons and the electron temperature near the pericenter of the orbit as the satellite approached the planet. At the same time, there was also an area with a hot electron gas, far from the pericenter at a distance of 180-200 thousand kilometers from the planet. This interesting phenomenon, differing from the normal concepts of distribution and temperature of electrons in near-planetary space, is linked with features of space near Mars. A charged particle spectrometer, registering ions of solar wind in energy ranges smaller than 10 kiloelectron volts, showed there was an area of thermal ions near Mars. The shape of the external boundary of this area and the discontinuity in the velocity flow in solar wind shows there may be a shock wave when solar wind interacts with the upper atmosphere of Mars.

Photography of the planet played an auxiliary role in experiments conducted by the Mars-2 and Mars-3 and was used for comparison with measurement results in other spectral intervals. At the same time, photographs taken by the Mars-3 at a great distance

showed the optical compression of the planet (as opposed to the dynamic), built up a relief profile according to the image of the edge of the disc where there was large expansion, and obtained colored pictures of the disc of Mars by synthesizing photographs taken with different light filters.

The photographs showed interesting twilight phenomena, especially luminescence of the atmosphere at approximately 200 km beyond the terminator line (boundary between day and night), and changes in the color of the surface near the terminator. The stratified structure of the Martian atmosphere can be traced on some photographs.

Further analysis of information will provide much valuable information on the nature of Mars.

The Face of the Red Planet

Professor B. Rodionov, Doctor of Technical Sciences

"Pravda", September 8, 1972.

Photography played an auxiliary role in the experiments conducted by Mars-2 and Mars-3. Nevertheless, those participating in the scientific research program into Mars anxiously and impatiently awaited the first photographs. This is quite understantable. Pictures of the Martian surface, taken at close range, provide valuable information on the nature of the planet. However, it was not easy to photograph the face of Mars, since it was covered by a veil of dust clouds. In September last year, a prolonged dust /179

storm of unusual intensity occurred on Mars and covered almost all the planet. Details which are normally observed well through ground telescopes could not be seen. Only some photographs showed high ground rising above the dust clouds, or parts of the terrain through small gaps.

At the beginning of December, ground observatories noticed that the Martian atmosphere was clearing up somewhat. But the dust storm increased its intensity. Some photographs taken by the Mars-2 and Mars-3 show certain formations of the Martian surface, but laborious processing by computer must be used to isolate these.

It is known that a satellite orbit is an ellipse, and the planet is in one of the focal points of this. The point in the orbit, nearest the planet, is called the pericenter, and the farthest the apocenter. When photographing near the pericenter the Mars-2 and Mars-3 only covered a small strip of terrain. If photography is done from further points of the orbit, the area of Martian surface covered by cameras increases, and at a certain distance the whole planet appears in a frame. Of course, the detail at great distances is reduced, although it is better than that of ground telescopes. The Mars-3 was in elongated orbit, the apocenter of which was much higher than the pericenter. The station passed near the planet at a distance of approximately 1,200 km every 12.5 days, and then moved away to 200,000 km. It was possible to carry out photography near the planet and far from it and observe specific regions of Mars and the planet as a whole.

Photographs of dust clouds in some regions were taken during photography near the pericenter. They were done using red, green and blue light filters. It was possible to synthesize colored photographs, investigate the physical and optical properties of Martian dust and, consequently, the composition of the planet's surface cover. The thickness of clouds and circulation of gaseous masses in the atmosphere is determined according to the nature of clouds and their variability during observations near the Martian horizon, along the vertical and in the transition zone from day to night (in the terminator). Therefore, new information can be obtained on the composition and structure of the atmosphere which will help to determine processes causing dust storms.

Scientists were extremely interested in photographs which covered the whole planet. It is known that the shapes of planets are not accurate spheres. For example, when we call the earth the terrestrial globe, this is only an approximation of its shape. In fact, the surfaces of planets have a complex shape, close to the so-called ellipsoids of revolution. In other words, planets are somewhat flattened and compressed near the polar axis. This compression is the result of centrifugal force when rotating. It is linked, to a certain extent, with the viscosity of planetary matter, the structure of its layers and the formation of its core, and also the gravitational field. Planetary matter does not fly into space due to centrifugal forces since they are balanced by the /180
internal forces depending on the factors mentioned above. Compression characterizes conditions in which this equilibrium is

achieved and, in this way, allows one to determine indirectly the planet's internal structure. In other words, determining planetary ellipsoids and their compression gives some indication of the similarity or difference in the internal structure of planets. Apart from this, information on planetary ellipsoids is required for compiling a geodetic coordinate system -- the basis for mapping.

The compression of planets is determined in two ways. One of these is the so-called dynamic and is based on observing the changes in the positions of natural satellite orbits in space. The orbits of satellites rotate (precess) relative to the stars due to the gravitational field of the planet. Ground observations have shown that the precession of Phobos and Deimos correspond to the compression of Mars, expressed by the figure 1/192.

The other method is the use of optical observations. These determine the geometric shape of the planet -- that which is directly visible to the observer. Once the optical "compression" of Mars was just over twice as great as its dynamic one. This difference was a mystery. If the first figure was correct, according to some scientists Mars can have a hypothetical model similar to that of earth. If the value based on ground optical observations is true, this means that the internal structure of the "red" planet is significantly different from that of the earth.

Observations from earth only give a rough estimation of Mars' compression. Therefore, it is extremely important to make this more accurate. The Mars-3 is helping to solve this problem. According to photographs transmitted, the optical compression was

more accurate than was observed from earth. Photographs are being processed to determine the optical compression.

The American astronomer V. Wright noticed that on photographs of Mars taken by ground telescopes using different light filters, the visible diameter of the planet in violet and blue rays was significantly greater than in red ones. The theory was put forward on the anomalous physical and optical formation of the Martian atmosphere, and especially the existence there of a certain violet layer at a great altitude. This was not supported by Soviet astronomers V. G. Fesenkov, V. V. Sharonov, N. P. Barabashov and others. On the basis of their theoretical and laboratory research, the phenomenon noticed by the American astronomer can be explained by purely photographic effects.

Processing of photographs transmitted by Mars-3 confirm that direct measurement, free from the photographic effects, agree well with evaluations made by academician V. G. Fesenkov.

Instruments on Mars-3 allowed the planet to be examined, as it were, from the side. It is shaped like a sickle. The nature of its tapered ends (or as specialists say, "horns") depends on the atmosphere. Spectral zonal photography of Mars during the sickle phases, which are not observed on earth, allows research to be made into the transfer of light energy in the atmosphere, which will enable its composition and structure to be determined.

Further processing of information in the photographs, and also information transmitted by other scientific instruments in the Mars vehicles, will help us to understand the nature of Mars --

the heavenly body most similar to earth. Study of the face of Mars will allow comparisons to be made with earth and, by the same token, give more knowledge of our own planet.

V. INTERNATIONAL COOPERATION

The "Interkosmos" Program in Action

V. Vereshchetin, the deputy chairman of the "Interkosmos" Council attached to the Academy of Sciences of the USSR

"Nauka i zhizn'", No. 7, 1972.

Joint work in the research and conquest of outer space is /181 one of the successfully developing spheres of all-round cooperation of scientists of socialist countries. This work opens new prospects for the wider use of the achievements of the scientific and technical revolution for developing the national economy of friendly countries and is one of the boundaries of socialist integration.

The First Steps

It was wrong to believe that everything started at zero when, in 1967, experts, representatives of nine socialist countries, gathered in Moscow to prepare the "Interkosmos" program. Cooperation between these countries in the study of space began, in fact, in 1957, when the first artificial earth satellite was launched. At this time, our joint efforts were limited mainly to optical observations of artificial earth satellites (visual, photographic and photometric). These observations, which are still important today, allow study to be made of the density of the atmosphere at an altitude of the satellite's perigee, the irregularity of the

earth's field of gravity, to set up geodetic links at great distances, carry out ephemeris survey which is required for forecasting the movement of satellites and controlling their scientific equipment.

Special stations for photographic observations of satellites were built in cooperating countries at observatories or universities and equipped with Soviet cameras. These stations are successfully carrying out their work in eight countries. A laser range finder which will operate at these stations is being developed by specialists of socialist countries to increase the accuracy of satellite observations. In 1963 the yearbook "Nablyudeniya iskusstvenn'kh sputnikov Zemli" [Artificial earth satellite observations] was published which contains scientific articles, accounts or work at stations and a chronicle of scientific deliberations.

The "Interkosmos" program opened a new stage in the development of cooperation in space -- a transfer from ground observations to joint development and launching of satellites and research rockets. The aim of the cooperating countries is not only to study space, but to put astronautical achievements into practical use. Nine socialist countries (Bulgaria, Hungary, the German Democratic Republic, Cuba, Mongolia, Poland, Rumania, the USSR and Czechoslovakia) decided to cooperate in four basic areas: space physics, communications, meteorology and medicine.

Work groups are permanently active in each of these areas. /182
The joint work of each of the countries is coordinated by national bodies set up in all cooperating countries. In the Soviet Union

these functions are carried out by a council for international cooperation in the field of research and use of outer space attached to the Academy of Sciences of the USSR.

Financing of the joint work enables successful cooperation to be made: there is no general financial fund or accounts linked with this; each country pays for the work which its specialists carry out. In accordance with this principle, the Soviet Union provides its partners with rocket and space technology serviced by the Soviet Union's command and instrumentation complex. The scientific results are available for all those participating in the experiments.

Whereas a few years ago we only spoke of plans of joint experiments in space, now international work has been done which has brought interesting scientific and practical results.

International Satellites and Rockets

The first joint satellite, the Interkosmos-1, was put into orbit on October 14, 1969. To date, six international satellites have already been launched.

Satellites in the Interkosmos series are designed for studying heliophysical and geophysical processes taking place on the Sun, in the earth's atmosphere and in interplanetary space.

The Interkosmos-1 and Interkosmos-4 contained scientific equipment from the German Democratic Republic, the USSR and Czechoslovakia for investigating the Sun's ultraviolet and X-ray radiation and its effect on the earth's atmosphere. This research

could only be done by satellites since this radiation does not penetrate the earth's atmosphere.

As a result, scientists obtained new information on the origin and development of solar flares, with which many processes in the earth's atmosphere are linked (breakdown of radio communication, magnetic storms, etc.). Apart from this, it was shown that at an altitude of approximately 100 km there is less oxygen than was thought previously.

In the near future "solar satellites" will be launched in the "Interkosmos" program with a wider selection of scientific equipment to use the 11-year cycle of solar activity for greater study of huge explosions on the Sun and to develop reliable methods for forecasting them.

The Interkosmos-2 satellite studied the physical characteristics of the ionosphere. Apart from Soviet equipment, developed by specialists in Bulgaria, the German Democratic Republic, the Soviet Union and Czechoslovakia, the satellite contained a dual-frequency "Mayak" radio transmitter produced in the German Democratic Republic.

Reliable radio communication on earth depends on the condition of the ionosphere, which changes depending on solar activity, the time of the year and the time of day. The 50-day observation carried out by the Interkosmos-2 gave scientists new information on the temperature distribution of electrons on a global scale, and detected an equatorial anomaly in the ionosphere at altitudes above 900 km.

The Soviet and Czechoslovakian Interkosmos-3 and Interkosmos-5 were designed for studying the radiation situation in near space, the radiation belts of earth and electromagnetic processes in the ionosphere. These satellites carried out simultaneous geophysical /183 and radiophysical research. The information obtained extended our knowledge of links between the Sun and earth and laws governing the propagation of low-frequency waves and so-called "whistling atmospherics" in the earth's ionosphere.

The Interkosmos-6 launched on April 7, 1972 varies considerably in construction and scientific assignment. This was the first satellite in the "Interkosmos" series which returned to earth.

The experiments carried out by the "Interkosmos" satellites are of a complex nature. Measurement by the satellites is combined with ground observations. Experience in the use of complex research was acquired in 1968 when the Kosmos-261 was operating. When the Interkosmos-1 and Interkosmos-4 were launched solar activity was studied simultaneously by instruments in the satellites and in ground observatories. Ionospheric research and study of low-frequen electromagnetic fluctuations, carried out by the Interkosmos-2 Interkosmos-3 and Interkosmos-5, were also accompanied by measurement done by a vast network of ground ionospheric stations in many countries.

Apart from satellite research, the "Interkosmos" program includes experiments using meteorological and geophysical rockets. These experiments provide information on the atmospheric cross section, including at altitudes not reached by satellites. At the

end of 1970 the Vertikal'-1 geophysical rocket was launched with a lift of approximately 500 km. The scientific equipment for the rocket was developed and produced by scientists of six socialist countries. The experiment included measurement of a number of structural parameters of the ionosphere, solar radiation and research into the physical and chemical properties of meteor particles.

This research was continued by the Vertikal'-2 rocket launched in August 1971. Simultaneous measurement by ionospheric stations in the German Democratic Republic and the USSR was done where the rockets were launched.

Scientists and engineers from socialist countries take an active part in all stages of the work with satellites and rockets -- from designing and producing scientific equipment to prelaunch tests and equipping the space vehicles.

Satellites and geophysical rockets in the "Intekosmos" program will be launched in the future. Some of the experiments, requiring statistical accumulation of material, will be repeated, and others conducted for the first time. The Soviet Union will equip its partners with improved rocket and space technology.

Joint work in space physics is not only limited to direct measurement from satellites and rockets. Above there was mention of the long-term work of optical observations by artificial earth satellites. Apart from this, coordinated observations between observatories and ionospheric stations is being carried out, joint theoretical work is successfully being done and systematic scientific meetings and discussions are held systematically. Laboratories

in several socialist countries are analyzing samples of lunar soil brought back to earth by Soviet automatic vehicles.

To Serve Mankind

Space science and technology is increasingly used for the practical needs of the national economy. /184 The development of astronautics in socialist countries is closely linked with solving such problems. They occupy the first place in the activity of working groups in space communication, space meteorology, and space biology and medicine, set up in accordance with the "Interkosmos" program.

On November 15, 1971, Bulgaria, Hungary, the German Democratic Republic, Cuba, Mongolia, Poland, Rumania, the Soviet Union and Czechoslovakia signed an agreement to form an organization and a communication system via artificial earth satellites. This system was available to all member states and was called "Intersputnik". It is based on equal and democratic rights and allows for the requirements and existing economical and technical resources of the countries.

A number of "Intersputnik" receiving and transmitting stations are being built. During the first experimental stage, participants in the system will have free use of satellite communication channels provided by the Soviet Union. Later, the system will operate commercially.

In satellite meteorology, cooperating countries are now transferring from joint development of methods for using information from meteorological satellites to the practical use of this information for weather forecasting. The complexity in solving these

problems, occupying an important place in world meteorological science, requires the joint effort of many countries.

Joint work in rocket sounding of the atmosphere is also devoted to studying processes taking place in the upper layers of the atmosphere and have a practical meaning for the weather service. Much attention is being paid to developing and improving technical sounding facilities, and developing equipment and instruments. Hence, specialists in the meteorological service of the German Democratic Republic have produced milar casings and metallized refractors for measuring wind speed at altitudes less than 90 km, which were successfully tested in November 1971 during the launches of Soviet meteorological rockets. In Volgograd, a group of Soviet and German scientists conducted an experiment at the rocket sounding station to measure the concentration of ions and electrons in the upper atmosphere, using Soviet rockets and instruments produced in the German Democratic Republic.

The joint efforts of specialists of many countries are helping to develop a complex of ground equipment for receiving information from meteorological satellites during direct transmission; this allows the meteorological services of socialist countries to make better use of information from satellites for weather forecasts.

An integral part of the "Interkosmos" program is the joint effort in space biology and medicine, conducted on 21 selected subjects. This work includes problems of space physiology, radiation safety in space flights and pharmocological and chemical protection from ionizing radiation. Interest in this work on an

international basis is explained by their value not only for the safety of astronauts, but to develop aviation medicine and normal "terrestrial" biology and medicine. Combining the resources of different scientific establishments, each of which has its own specific character, experience and developed methods of research, is extremely useful. The cooperation has already shown concrete results, scientific articles have been published jointly, and new research equipment has been produced.

During the five years which have passed since the "Interkosmos" program was begun, cooperation between socialist countries in the /185
research and use of space has occupied the main place in international programs for space research, and become an important factor in the scientific and technical progress of socialist countries.

The Geography of Cooperation

Cooperation in space goes beyond the boundaries of countries in the socialist countries.

On almost every continent there are stations for carrying out optical observations of artificial earth satellites, equipped with high-precision Soviet cameras.

Soviet meteorological rockets are sounding the atmosphere from the international research proving ground in India.

Soviet and French high-altitude aerostats have repeatedly taken up scientific equipment for conducting geophysical research into the magnetic and associated points on earth from the Soviet Union and on the island of Kerguelen in the Indian Ocean.

The launch of the French "SIS" satellite with a Soviet launch vehicle in April this year was a new step in the successful development of Soviet-French cooperation in space, which already includes a great number of joint experiments conducted, using satellites and rockets.

After an agreement was signed between the Academy of Sciences of the USSR and NASA in the USA in January 1971, there was an increase of activity in space study between Soviet and American scientists.

The conquest of space is becomming truly international.

The declaration, made during the 24th congress of our party on the readiness of the Soviet Union to increase the mutually beneficial cooperation with other countries in the research and conquest of space, is indeed being fulfilled.

A TASS Report: The Interkosmos-6 in Flight

"Pravda", April 8, 1972.

The Interkosmos-6 artificial earth satellite was launched in the Soviet Union on April 7, 1972 in accordance with a program of cooperation of socialist countries for the research and use of space for friendly purposes.

The satellite was put into orbit with parameters:

-- minimum distance from the earth's surface (in the perigee) -- 203 km;

-- maximum distance from the earth's surface (in the apogee) -- 256 km;

-- the initial orbital period -- 89 min;

-- orbital inclination -- 51.8°.

The Interkosmos-6 satellite is designed for studying:

-- primary cosmic radiation particles with an energy of 10^{12}-10^{13} electron volts;

-- the chemical composition and electrical spectrum of cosmic rays in the high-energy range;

-- meteor particles in near space.

For conducting research into primary cosmic radiation the /186
satellite is equipped with a photographic emulsion unit and an ionization calorimeter with an overall weight of 1,070 kg, produced in the Soviet Union according to the technical requirements, developed by specialists in Hungary, Mongolia, Poland, Rumania, the Soviet Union and Czechoslovakia.

Apart from this, the satellite is installed with equipment for investigating meteoric matter, designed and produced jointly by Hungary, the Soviet Union and Czechoslovakia.

According to telemetering information in the satellite, the equipment is working normally.

A New Envoy of Friendship

"Moskovskaya pravda", April 8, 1972.

The TASS correspondent asked academician S. N. Vernov, the director of the Scientific Research Institute of Nuclear Physics of the Moscow State University, to give a report on the task and features of this new space experiment.

"The most important task for the Interkosmos-6 is the complex study of cosmic rays beyond the earth's atmosphere. Cosmic rays are nuclei of different chemical elements, moving in interstellar space with velocities close to the speed of light. The majority of them are hydrogen nuclei (protons).

The study of cosmic rays is of great interest for two fields of science -- the physics of high-energy particles and astrophysics. Research in this direction has brought about important discoveries: the existence of a positron was detected -- the first antiparticle, μ and π mesons were discovered, and also some hyperons. Study of the interaction of high-energy particles (more than 1,000 billion electron volts) nowadays is only possible in cosmic rays, since "terrestrial" accelerators of particles of such energies have not been produced. We know that this involves enormous expenditure of resources and requires much time.

It will not be an exaggeration if we say that hardly any astrophysical phenomenon could be understood without knowing the nature of cosmic rays and their origin. Side by side with radio- and gamma radiation there are rays which carry information on processes occurring deep in other galaxies. These are important when investigating the Sun.

Physicists have been using cosmic rays for a long time when studying the interaction of elementary particles with high and superhigh energies. However, the atmosphere prevents experiments of this type on earth. High-energy particle fluxes even in mountainous regions (3-4 km above sea level) are extremely small. Apart from

this, "newcomers" from space, normally, move deep inside the atmosphere and are accompanied by secondary particles created when they interact with nuclei of the earth's gaseous envelope. It is extremely difficult to isolate cosmic (primary) particles from their "fellow-travelers". This can be overcome if equipment is sent beyond the atmosphere.

The Soviet Union has produced powerful rockets and launched scientific space stations in the Proton series, designed for recording cosmic particles with an energy from tens of billions to millions of billions electron volts, and also for studying their energy spectrum and nuclear composition.

In assignment, the new experiment is a logical development of research begun by the Proton stations. The Interkosmos-6 uses improved equipment and a new method for recording particles. This /187 broadens the research and obtains more detailed characteristics of the interaction with proton matter of great energy.

A large number of scientists from the following socialist countries took part in preparing this experiment: Hungary, Mongolia, Poland, Rumania, the Soviet Union and Czechoslovakia.

The large number of countries participating in the experiment carried out by the Interkosmos-6 space scientific station shows that the problems of the physics of high-energy cosmic rays, examined beyond the earth's atmosphere, are attracting a wider circle of scientists. We hope that this cooperation will develop successfully in the future".

The Interkosmos-6 in Flight

"Pravda", April 11, 1972.

The Flight Control Center, 10. (TASS). The Interkosmos-6 satellite, launched in accordance with a cooperation program between socialist countries into space research, has been in orbit for four days.

It completed 46 revolutions around the earth on April 10.

The scientific equipment, developed by specialists from Hungary, Mongolia, Rumania, the USSR and Czechoslovakia, designed for investigating primary cosmic radiation, is working normally. Several communication sessions have already been held with the satellite. The information obtained shows that the pressure, temperature and energy consumption in the satellite corresponds to estimations.

Work is being done to carry out the experiment's scientific program. It began immediately after the Interkosmos-6 was separated from the final stage of the launch vehicle and power was supplied to its scientific equipment. After the first revolutions, photorecorders registering the results of the interaction of primary cosmic particles with atomic nuclei, were switched on from earth. During the satellite's first revolution, orientation was done so that the input "window" of the instrument was permanently directed towards the particle fluxes.

A check of the instrument's serviceability and correction to equipment sensitivity to telemetering information coming from the satellite was done during the first days of the flight. Specialists

are evaluating its operation and controlling individual systems and the satellite as a whole by the information arriving from it on its equipment and systems.

The incoming information is being operationally processed.

According to the "Interkosmos" Program

"Pravda", April 21, 1972.

The Interkosmos-6 satellite, launched on April 7, has returned to earth. The experimental material obtained has been sent to scientific research institutes for analysis and processing. The Pravda correspondent asked Academician B. N. Petrov, the chairman of the Council for International Cooperation in the "Interkosmos" Research and Use of Outer Space Program, to show the importance of this experiment.

Q: What new information do scientists hope to obtain as a result of the flight and the return to earth of this satellite? /188

A: As already reported, equipment in the Interkosmos-6 is designed for investigating the chemical composition and the energy spectrum of cosmic rays, and also the interaction of high-energy particles of primary cosmic radiation on atomic nuclei. Similar research was conducted earlier by Soviet scientists using heavy artificial Proton satellites. However, this experiment by the Interkosmos-6 is being done by a new method, which will return the scientific equipment back to earth, including a nuclear photographic emulsion unit. This contains a picture of the nuclear interaction

of high-energy particles, which cannot be obtained on earth even using the largest accelerators. When they have deciphered "traces" of these processes, scientists will obtain new information for understanding the acceleration of elementary particles with high energies, and explaining the nature of cosmic rays.

The use of a nuclear photographic emulsion for recording particles of cosmic rays also determined the flight features of the satellite -- its orbit and the time it remained in it. The flight lasted four days. This was necessary to obtain sufficient information on particle interaction. It was inadvisable to keep the equipment in space any longer, since this can cause the photographic emulsion to darken and, consequently, mean a partial loss of scientific information.

The orbital parameters and the flight features of the Interkosmos-6 were also used for another experiment -- studying the properties of meteoric matter in near space. The equipment which studied meteor particles was also returned to earth.

Q: Please tell us of the part played by scientists of different countries in preparing and conducting the Interkosmos-6 experiment.

A: Scientists of the following six socialist countries agreed to carry out this experiment several years ago when they met in Moscow -- Hungary, Mongolia, Poland, Rumania, the USSR and Czechoslovakia. Later, the technical design of the scientific equipment was prepared and approved. It was decided to produce the main instrument in the Soviet Union at the Space Research

Institute of the Academy of Sciences of the USSR. The electronic part of the equipment and its adjustment was done by workers at the Scientific Research Institute of Nuclear Physics of the Moscow State University. The experiment program was also the result of the collective work of scientists of six socialist countries. They are now helping to process the material obtained.

The emulsion unit is being taken to the Joint Institute of Nuclear Research at Dubna, where initial processing of the nuclear photographic emulsion will be carried out by physicists from socialist countries. They will use material and equipment developed by Polish and Czechoslovakian specialists. Later, it will be sent to all countries taking part in the experiment for further research by two methods, developed by Polish and Soviet scientists. This will allow the material obtained to be analyzed by many specialists, using the technical resources of various scientific laboratories.

We believe that this cooperation will provide the best research results in the shortest time. As a whole, experiments by the Interkosmos-6 have allowed another important part of the international cooperation program between socialist countries into space research to be carried out.

Q: What are the basic research directions envisaged by this program?

A: The "Interkosmos" program was developed when scientists /189 from socialist countries met in April 1967 in Moscow. It includes research into space physics, space meteorology and aeronomy, space communication and space medicine and biology. In accordance with

this program, over the past years the Soviet Union has launched six artificial earth satellites, two Vertikal' geophysical rockets, and several meteorological rockets with scientific equipment produced by scientists of socialist countries. Specialists from these countries are also conducting a wide program of coordinated ground observations.

These experiments have provided several interesting scientific results in the study of ultraviolet and X-ray solar radiation, the properties of the ionosphere and magnetosphere, the earth's radiation belts and cosmic rays.

On November 15, 1971, representatives from nine socialist countries signed an agreement in Moscow for setting up an organization and a space communication system -- "Intersputnik".

This joint research also includes the use of meteorological information obtained by Meteor satellites. The cooperation between socialist countries is also being successfully developed in space biology and medicine.

Many large scientific establishments and manufacturers from socialist countries are taking part in joint space research. Their workers have developed and produced complex instruments which have worked well in space. Specialists from the Soviet Union are contributing much to the "Interkosmos" program. The joint efforts of scientists from socialist countries for the friendly conquest of space will make it possible to use the combined resources of our countries for scientific and technical progress. Until now, we have dealt with the cooperation of socialist countries in the

"Interkosmos" program. Soviet scientists are also working with scientists from other countries.

We are cooperating successfully with the French National Space Research Center. As is known, several joint experiments have already been conducted. The Mars-3 automatic station was equipped with the French "Stereo" for investigating solar radio-frequency radiation in the meter wave band. The laser reflector in the Lunokhod-1 was produced in France. In the Oreol satellites, the Franco-Soviet "Arkad" project was carried out in studying the physical phenomena in the earth's upper atmosphere and investigating the nature of polar auroras. A number of joint experiments were made in Soviet and French meteorological rockets. On April 4, the Soviet launch vehicle, which sent the Molniya-1 communication satellite into orbit, simultaneously launched the French small independent "SIS" satellite, designed for technological purposes -- studying the characteristics of solar batteries in space conditions.

Joint ground stations have been set up in 15 collaborating countries, including several in Asia and Africa, for carrying out optical observations of artificial earth satellites. In January last year, an agreement was signed between the Academy of Sciences of the USSR and NASA in the USA on cooperation in several directions for the study and use of outer space. Recommendations, developed in accordance with this agreement, envisaged the implementation of a series of coordinated investigations into near space, the moon and planets, the study of the natural medium surrounding us from space, space meteorology, and also space biology and medicine.

Specialists from both countries are examining the technical /190
resources for developing joint facilities for the approach and docking of Soviet and American spacecraft and stations.

The Soviet Union is also cooperating with several other countries.

The Interkosmos-6: The Flight Is Over, the Experiment Continues

(TASS)

"Sovetskaya Rossiya", April 21, 1972.

The Scientific Research Institute of Nuclear Physics of the Moscow State University has begun to process material brought back to earth by the Interkosmos-6 satellite, launched on April 7.

The satellite was designed for studying primary cosmic rays with an energy of thousands of billions of electron volts, their energy spectrum and chemical composition, and also meteor particles in near space.

The Interkosmos-6 scientific program was developed by a team of scientists from six socialist countries: Hungary, Mongolia, Poland, Rumania, the Soviet Union and Czechoslovakia.

At the request of the TASS correspondent, one of the directors, Professor N. L. Grigorov, of the Moscow University, reported on the unique experiment -- the study of cosmic rays:

"One can study the nature of a cosmic ray particle and the result of its interaction with an atomic nucleus more reliably and accurately if one uses special photographic materials -- thick

"packets" of photographic emulsion. Then, each particle and its interaction with silver bromide is fixed in the photographic emulsion in the form of a special trace or, as physicists say, a track, which can be investigated in every detail. We in the international space program for socialist countries first adopted this method for recording particles, having an energy of thousands of billions of electron volts. The processing of material brought back to earth during the Interkosmos-6 program will undoubtedly give us new information on the behavior of high-energy particles in matter. The emulsion unit (Fig. 31), which was installed in the satellite, is large and contains 45 liters of photographic emulsion. These cosmic ray "sensors" are notable for the novelty of design. They were produced in the Soviet Union and the space experiment was conducted for the first time.

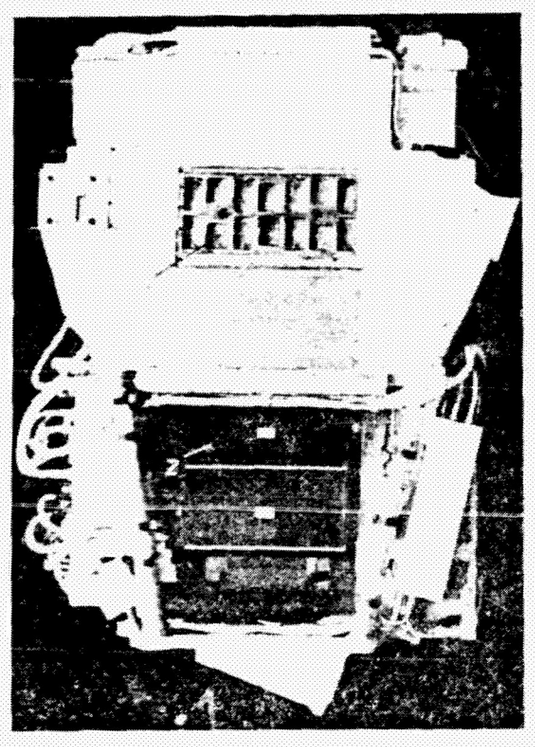

Fig. 31. An external view of the instrument for conducting research into primary cosmic radiation, which was installed in the Interkosomos-6 satellite. 1 - Photographic emulsion unit; 2 - Ionization calorimeter.

From this new position we had to approach the solution of problems linked with recording each particle. It is important for a scientist to find on a photographic plate a certain particle, and not another one similar to it. In the Interkosmos-6,

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there were accurate photorecorders of the coordinates of particle trajectories. Photographic material brought back to earth will help to interpret the trajectory of each particle and explain its fate.

This method combined the two most effective means of recording energy particles: by their traces on thick photo emulsion and by electronic devices.

Using an emulsion as a basic cosmic ray particle recorder also determined the features of the experiment in the Interkosmos-6, its orbit and flight duration. Calculations showed that the four-day stay of the emulsion unit in orbit was sufficient to obtain the necessary information. It would have been undesireable for it /191 to remain longer in space, since traces from particles of different energy begin to "superimpose" each other and can cause the photographic emulsion to darken. This would mean a loss of information.

Little time was required for preparing the equipment for the Interkosmos-6 flight. Specialists from all six countries actively participated in developing the experiment and choosing the most effective types of instruments. The research program was discussed, the technical design was examined and approved, and requirements were formulated for the scientific equipment. It was produced by the Space Research Institute of the Academy of Sciences of the USSR, the Scientific Research Institute of Nuclear Physics of the Moscow State University, and a number of collectives.

An important stage of this experiment is the research into the photographic emulsion on earth after the Interkosmos-6 returns. The material obtained must be developed: there are traces of the

interaction of high-energy particles with matter deep in the sensitive layer in cryptic form. The emulsion was developed in the high energy laboratory at the Joint Institute of Nuclear Research in Dubna. The emulsion leaves will be glued to special slides, which were prepared by Czechoslovakian specialists, and then developed.

The slides with the emulsion glued on them are cut into very thin sections by a special machine, produced by Polish specialists. Then, half of the processed material will be taken to the Cracow Institute, where Polish scientists will investigate the traces of the interaction of heavy nuclei of cosmic rays on the photographic emulsion. Some of the material will be sent to Bucharest; here, specialists from Hungary, Rumania, Czechoslovakia and the Soviet Union will combine efforts and use a method suggested by Polish scientists.

After completing this part of the program, the emulsion /192
material is divided among research teams of all the participating countries. During the following stage of the experiment a method will be used which was developed by the Soviet Union.

The cooperation of scientists from socialist countries has made it possible to study this important scientific problem, effectively use various technical facilities, and carry out a rational "division of labor".

A TASS Report: Interkosmos-7

"Pravda", July 1, 1972.

On June 30, 1972 the Soviet Union launched the artificial earth satellite Interkosmos-7 in accordance with the cooperation program between socialist countries in the research and use of outer space.

The Interkosmos-7 is designed for continuing joint research, begun by the Interkosmos-1 and Interkosmos-4, into solar ultraviolet and X-ray radiations and their effect on the earth's upper atmosphere. The satellite contains scientific equipment developed and produced by specialists in the German Democratic Republic, the USSR and Czechoslovakia.

The Interkosmos-7 satellite went into orbit with the following parameters:

-- minimum distance from the earth's surface (in the perigee) -- 267 km;

-- maximum distance from the earth's surface (in the apogee) -- 568 km;

-- initial orbital period -- 92.6 min;

-- orbital inclination -- 48.4°.

Specialists from the German Democratic Republic, the USSR and Czechoslovakia took part in the assembly and scientific equipment testing in the satellite when it was prepared for the launch. The satellite's flight was controlled by an operational group, consisting of specialists from the German Democratic Republic, the USSR and Czechoslovakia.

The satellite's scientific equipment is working normally.

Ground stations in the instrumentation complex are receiving scientific information from the satellite.

Simultaneously with measurement carried out by the Interkosmos-7, observatories in socialist countries are conducting radio astronomical, ionospheric and optical observations according to a coordinated program.

A Solar Watch in Orbit

(TASS)

"Sovetskaya Rossiya", July 1, 1972.

On June 30 the Interkosmos-7 satellite began observations outside of the earth's atmosphere, using scientific instruments produced by scientists in the German Democratic Republic, the USSR and Czechoslovakia. It is successfully continuing solar research begun by the Interkosmos-1 and Interkosmos-4 automatic vehicles, according to an international space program for socialist countries. The aim of this work is to investigate the "pulse" of the Sun and study its effect on geophysical processes. A TASS observer, D. Dmitriyev, asked Professor S. L. Mandel'shtam, the scientific director of this important international experiment, to report on the research carried out by the Interkosmos-7.

"The new satellite is very similar to its predecessors, Interkosmos-1 and Interkosmos-4. Of course, the research instruments have been improved and modernized, using the experience of /193

previous launches. However, the tasks and main aim of the work are almost the same. This allows us to compare fresh information with results already obtained, and make the necessary deductions.

Here are a few examples. The Interkosmos-7 (Fig. 32) contains instruments produced in the German Democratic Republic. They record short-wave solar radiation in wave bands of 1,200-1,300 angstroms, of special interest to researchers. These waves do not reach the earth's surface, since they are absorbed by oxygen molecules. Naturally, it is most important to know the intensity of these rays, and how they change in time in order to understand phenomena which determine the nature of the radiation of the "quiet Sun".

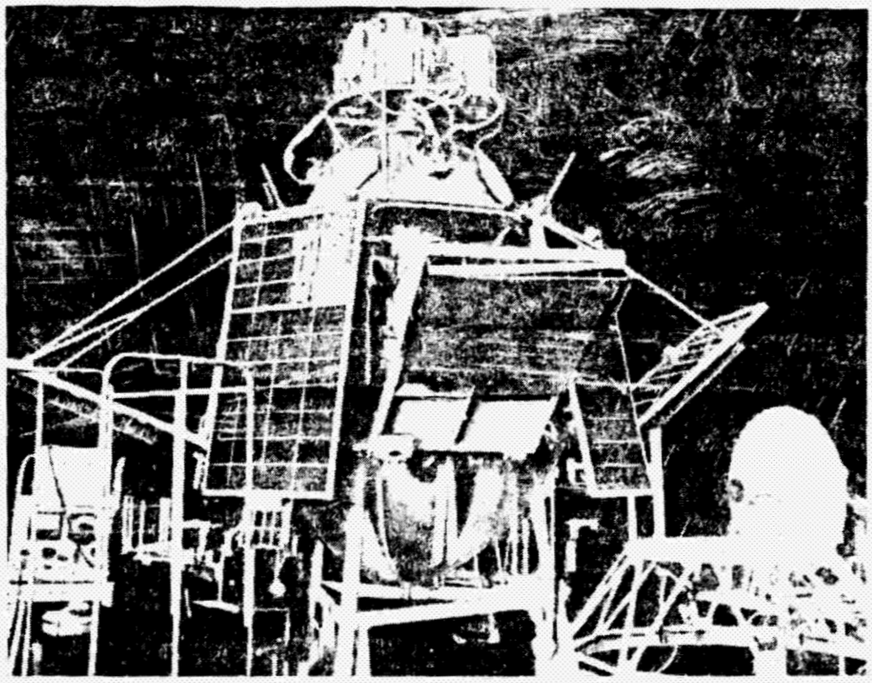

Fig. 32. The Interkosmos-7 in the assembly-and-test building.

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Apart from this, scientists receive a double benefit, as it were, by installing such instruments into satellites. When an automatic vehicle is in the earth's shadow, it is possible to record the amount of molecular oxygen in the atmosphere by the intensity with which they are absorbed by solar rays. This work was begun by the Interkosmos-1. It was found that upper layers of the atmosphere contain half as many oxygen molecules as was assumed earlier. Subsequent experiments, in particular by the Interkosmos-4, showed that the amount of oxygen at altitudes of approximately 100 km changes, and depends on the time of day, the state of the atmosphere and many other factors. Naturally, this information must be repeatedly confirmed. The Interkosmos-7 will shed new light on this. All this is due mainly to development work carried out by scientists in the German Democratic Republic.

In Czechoslovakia specialists have produced original and highly sensitive instruments for a number of Interkosmos satellites, which record hard X-ray solar radiation. This equipment can detect /194 rays which form when powerful solar flares occur. It was interesting to compare a picture of these natural phenomena with observations from earth and from space. X-rays do not reach the earth -- the atmosphere absorbs them. Therefore, ground observatories detect solar flares in rays of the optical band. Apparently, "X-ray flares" on the Sun occur more often than normal ones observed from earth. Instruments in the Interkosmos-4 detected more than 100 such phenomena, some of which were not seen by astronomers.

Now, when there is little solar activity, it is important to continue observations of its radiation in hard, ultrashort, X-rays. Judging by forecasts from the solar survey, only individual flares are possible in the near future. Obtaining a detailed picture of the development of each of these, in order to understand the nature of the phenomena, is a tempting prospect for researchers.

An important contribution to international space experiments is that of Soviet scientists producing a series of unique instruments for the "solar watch" in the Interkosmos program. All three specialized satellites, the first, fourth and seventh, were equipped with Soviet X-ray polarimeters and spectrometers. They helped to determine that "X-ray flares" on the Sun occur as the result of the interaction of ions, drifting in the Sun's farthest layers, with powerful electron flows, rapidly "falling" from the external to the deeper layers of the Sun's atmosphere. Scientists hope that this experiment by the Interkosmos-7 will obtain new information substantiating previous deductions.

Study of the spectrum of X-ray flares on the Sun, obtained by equipment in the Interkosmos satellite, gave interesting results. Soviet instruments detected the spectra of several X-ray flares. It was found that in the region of the flares there were ions of atoms of iron which, when affected by high temperatures, only retained one or two electrons. Matter can only exist in this state at a temperature of approximately 20-30 million degrees.

Many such examples could be given. Each new experiment in space gives valuable information on the nature and activity of

the Sun, and of the close link of its activity with processes on earth.

Observatories in Bulgaria, Hungary, the German Democratic Republic, Rumania, the Soviet Union and Czechoslovakia will conduct complex observations according to a special program while the Interkosmos-7 is in orbit".

The Scientific Watch of the Satellite of Friendship

(TASS)

"Pravda", January 23, 1972.

A meeting was held on January 21 in the presidium of the Academy of Sciences of the USSR by the operational and technical group from the USSR and Czechoslovakia who controlled the Interkosmos-5 satellite, launched on December 2, 1971.

The scientific equipment and on-board systems in the satellite are working normally. By January 21, 1972 the Interkosmos-5 had completed 740 revolutions around the earth. Instruments in the Interkosmos-5 recorded a number of interesting phenomena when studying charged particle fluxes in the lower boundary of radiation belts, and when observing low-frequency electromagnetic fluctuations in the ionosphere.

Geophysical stations and observatories in the USSR, Czechoslovakia, Bulgaria, the German Democratic Republic, France and New Zealand are taking part in ground observations, which are being conducted simultaneously with measurement in the Interkosmos-5. /195

The joint Soviet-Czechoslovakian experiment is continuing successfully.

The Interkosmos-8 Investigates the Ionosphere

(TASS)

"Pravda", December 2, 1972.

The Interkosmos-8 artificial earth satellite was launched in the Soviet Union on December 1, 1972 in accordance with a cooperation program between socialist countries in the research and use of outer space for friendly purposes.

The satellite is designed for continuing research into the earth's ionosphere: the concentration of electrons and positively charged ions near the satellite, and the temperature of electrons and their integral concentration between the satellite and the earth's surface. Apart from this, electron flows with an energy greater than 40 kiloelectron volts, and protons with an energy of greater than 1 megaelectron volt will be recorded.

The Interkosmos-8 was sent into orbit with the following parameters:

-- minimum distance from the earth's surface (in the perigee) -- 214 km;

-- maximum distance from the earth's surface (in the apogee) -- 679 km;

-- initial orbital period -- 93.2 min;

-- orbital inclination -- 71°.

The satellite contains the following scientific equipment:

-- an electronic unit for ion traps and a Langmuir probe, developed and produced by specialists in Bulgaria;

-- a Mayak radio transmitter and a signal conditioning unit for recording readings from the Langmuir probe onto the satellite's memory, developed and produced in the German Democratic Republic;

-- an electronic unit for a high-frequency probe, developed and produced by scientists and specialists in Czechoslovakia;

-- instrument sensing elements for measuring the parameters of the ionosphere, semi-conductor and gas-discharge high-energy electron and proton counters, developed and produced in the Soviet Union.

The scientific equipment was prepared for the launch at the cosmodrome by specialists of countries participating in the experiment.

The scientific equipment and all the satellite's systems are working normally. Receiving stations of the ground command and instrumentation complex are regularly receiving information from the satellite.

A wide network of ground geophysical observatories and ionospheric stations in socialist countries is carrying out ionospheric observations and receiving signals from a radio transmitter in the satellite, simultaneously with measurement made by the Interkosmos-8.

An operational group, consisting of specialists from Bulgaria, the German Democratic Republic, the Soviet Union and Czechoslovakia, is controlling the satellite's scientific equipment.

Research in the "Interkosmos" Program

"Pravda", December 2, 1972.

In connection with the launch of the Interkosmos-8, the /196
"Pravda" correspondent asked Academician B. N. Petrov, the chairman of the committee for international cooperation in the research and the use of outer space, Interkosmos, to answer a series of questions.

Q: What research is being conducted in the "Interkosmos" program?

A: Different radiations, solar, galactic and also cosmic particle and micrometeorites are constantly penetrating the earth's atmosphere. These phenomena affect the weather and climate, radio communication, many biological processes, and through them -- man's practical activity. Therefore, there is a need for comprehensive research into complex processes occurring in space, and their uniformities must be explained.

However, individual space experiments cannot give sufficient information on these processes. They must be studied according to a long-term systematic program. Scientists from socialist countries bore this in mind when they developed the "Interkosmos" program.

It is working successfully. Scientific information has been acquired on many aspects of space physics. Observations on the active regions on the Sun, and sources of short-wave ultraviolet and X-ray radiations have been made by Interkosmos-1, -4 and -7 satellites. The Interkosmos-3 and Interkosmos-5 investigated

low-energy cosmic rays in the earth's radiation belts and low-frequency radiation. Ionospheric and magnetospheric processes were studied by the Interkosmos-2 and the Vertikal'-1 and Vertikal'-2 geophysical rockets.

Scientific equipment is being improved with each experiment, experience in cooperation between scientists of socialist countries is being developed, and our concepts of space and processes taking place there are being broadened.

Q: What are the features of the experiment now being conducted?

A: Its program is aimed at continuing ionospheric research, begun by the Interkosmos-2 and geophysical rockets. The main feature of the Interkosmos-8 is that its orbit is more inclined towards the equator than previous satellites. Therefore, it will pass through regions of the ionosphere in high latitudes, and intersect polar aurora zones in the earth's geomagnetic poles.

In these regions, the planet's magnetic field affords greater penetration to solar radiation particles. Therefore, the link between geophysical and geomagnetic processes can be traced here more accurately. Furthermore, the study of polar auroras, geomagnetic storms and other phenomena can be a more direct method for understanding the links between the Sun and earth.

The Interkosmos-8 has more scientific equipment than the Interkosmos-2, and it was produced by specialists from a number of socialist countries. Bulgaria produced an electronic part for an instrument for measuring the concentration of positive ions in the

upper atmosphere. Czechoslovakian scientists developed an electronic unit in the equipment for measuring electron temperature. Sensor elements for these experiments were produced in the Soviet Union. An original intermediate memory was produced by specialists in the German Democratic Republic. This accelerates the recording process of information on electron concentration and temperature in the ionosphere, and gives a more detailed picture of the process studied. The German Democratic Republic also produce a two- /197
frequency Mayak radio transmitter, which can sound the ionosphere between the satellite and ground receiving stations.

Q: What is the future for the Interkosmos program?

A: In the next few years, scientists from socialist countries will continue scientific experiments from satellites and geophysical rockets. At the moment, specialists from Hungary, the German Democratic Republic, Poland, the Soviet Union and Czechoslovakia are working to produce a unified telemetry system for receiving scientific information from satellites, launched in the Interkosmos program. The fact is, that at the moment, information is received and recorded, mainly, in the Soviet Union. With a unified system, this can be done by all socialist countries. They will also take a greater part in the operational control of experiments, which is extremely important when investigating high-speed processes, for example, solar flares.

A number of events will take place in 1973 to commemorate the 500th anniversary of the birth of Nicholas Copernicus. Scientists from the German Democratic Republic, the Soviet Union and

Czechoslovakia are preparing another experiment to investigate the electromagnetic links between the magnetosphere and the ionosphere.

An Envoy of Friendship

L. Vedeshin, a worker at the Interkosmos Council attached to the Academy of Sciences of the USSR

"Vechernaya Moskva", December 2, 1972.

The new Interkosmos-8 artificial earth satellite, launched on December 1, is continuing ionospheric research, begun by the Interkosmos-2 and the Vertikal'-1 and -2 geophysical rockets.

Scientists throughout the world are interested in experiments to study the processes taking place in the earth's ionosphere, since they occupy an important place among other research into the physical properties of outer space, conducted according to the Interkosmos program.

The earth's conducting envelope, the ionosphere, consists of charged particles. It affects the propagation of radio waves, partially absorbs long waves, and reflects short waves. Short-wave radio communication is possible far beyond the limits of the earth's horizon between any points on the planet.

The ionosphere has a complex structure, it is non-uniform both in altitude and in geographical position (latitude and longitude). Scientists have proved that its condition changes depending on solar activity, the time of the day and time of year.

Calculation of radio wave propagation, and the theory of producing various ion sensors and micromotors, required for the orientation of spacecraft, requires detailed knowledge of the physical mechanism of processes taking place in the ionosphere. Here, scientists put great faith in space vehicles. Satellites can measure the parameters of the ionosphere along their orbit. Experiments with rockets give a "vertical section" of the upper atmosphere, a distribution of its parameters according to altitude.

The scientific program for the Interkosmos-8 is of a complex nature. It includes on-board probe measurement of different parameters of ionospheric plasma, and ground observations of the propagation of radio signals from the Mayak transmitter in the satellite.

Scientific instruments for the experiment were developed and produced in Bulgaria, the German Democratic Republic, the Soviet Union and Czechoslovakia. Bulgarian and Czechoslovakian scientists produced electronic units, which control the Soviet instruments, /198 measuring the concentration and temperature of charged particles.

Specialists from the German Democratic Republic produced an intermediate memory for the Bulgarian instrument. This can obtain a more detailed picture of the distribution of concentration and temperature of electrons along the flight path.

Apart from this, scientists from the German Democratic Republic produced the Mayak radio transmitter for probing the atmosphere between the satellite and numerous ground receiving stations. These stations, receiving signals from the transmitter are in Bulgaria,

Hungary, the German Democratic Republic, Cuba, Poland, Rumania, the Soviet Union and Czechoslovakia. They are equipped with standard receivers.

Scientists are also interested since, for the first time in the Interkosmos program, the experiment is conducted from near-polar orbit near the geomagnetic poles. In this orbit, the earth's field offers less resistance to solar plasma in the atmosphere, and the link between geophysical and heliophysical processes here is more clearly expressed.

Study of such phenomena as polar auroras, and the earth's current system can be a more direct method for understanding links between the Sun and earth. Joint space experiments will bring about the progress of science in all countries taking part in them.

The USSR and France: A Broadening of Space Cooperation

S. Petrunin, a worker at the Interkosmos Council attached to the Academy of Sciences of the USSR (TASS)

"Moskovskaya pravda", April 6, 1972.

The launch in the Soviet Union of a launch vehicle for the Molniya-1 communication satellite and the French SIS (small independent satellite)[1] is proof of the increasing cooperation between the Soviet Union and France in space research. Joint experiments by scientists of both countries include problems of space physics, satellite meteorology, rocket probing of the atmosphere, space communication, medicine and biology.

1 A TASS report on the SIS launch can be seen in section 2 (author's note).

The successful use of the French light reflector in the Lunokhod-1, the extremely interesting information in the joint Stereo experiment in the Mars-3, and the launch of the Oreol satellite have been important achievements in a wide program of cooperation between the USSR and France in space study.

Another important event occurred when a Soviet launch vehicle put a French satellite into orbit. Incidentally, when it was decided that scientists from both countries should conduct this experiment, it was agreed that the French satellite should be put into orbit simultaneously with the Soviet one to conserve the power of the launch vehicle.

The small independent satellite (Fig. 33) is designed for carrying out complex, technological experiments in space. These include study of various materials, and the efficiency of on-board systems, assemblies and instruments in space flight. These are the main differences between such satellites and scientific laboratories, where the nature of the surrounding medium is studied. "Technological satellites" are required to solve technical

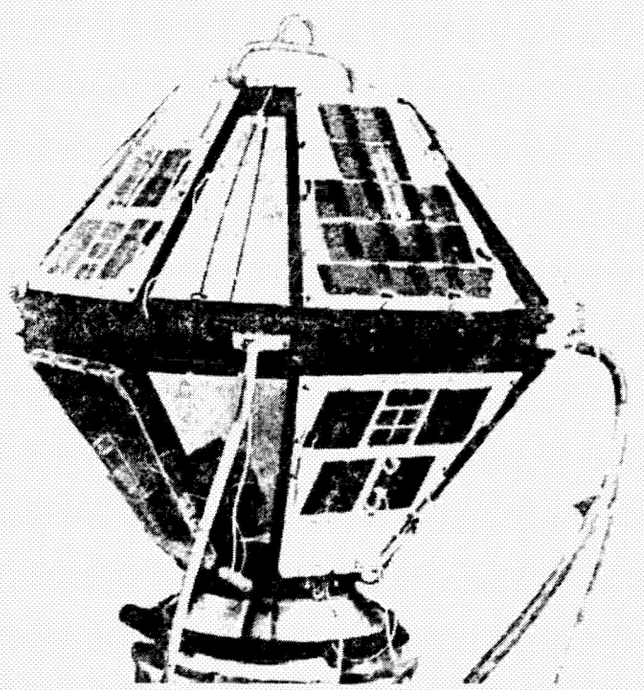

Fig. 33. The French small independent satellite (SIS).

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and engineering problems linked with the further improvement of /199
scientific stations and observatories, operating in space. The French independent satellite is designed for studying the effect of space conditions on solar batteries: radiation and sharp changes of temperature.

Of course, photoelectric cells can be protected from direct radiation, but this increases the satellite's weight. It is better to develop semi-conductor materials which hardly react to the radiation background of space.

Sharp temperature gradients also affect photoelectric cells. When in orbit, the satellite is heated by solar rays, then cools when it enters the earth's shadow. The temperature of solar batteries varies, and for this reason they quickly become unserviceable. The SIS is testing the elements of solar batteries developed by French scientists.

The satellite has thin cadmium-sulfide and cadmium-telluride batteries. There are also standard silicon batteries providing power for the SIS. Specially-made individual silicon elements are fitted on the same planes as the experimental batteries. The comparative information obtained will determine the rate of deterioration of different elements and their protective coatings.

The two satellites were sent into orbit, using one launch vehicle, in sequence. At first, the Soviet Molniya-1 communication satellite was separated from the rocket and went into independent flight, followed by the French satellite. To remove the second vehicle from the launch vehicle and to prevent the satellites from

colliding, the French satellite was given an acceleration of approxi- /200
mately 1 m/sec from a special pyrotechnic system, and went into its own orbit. Repeated, crucial tests of the satellite were made in France and in the Soviet Union to solve this extremely technical problem.

At first, the experiments were conducted in France using stationary and mobile equipment. A space vacuum, solar radiation and space temperatures were produced artificially. Complex checks showed that all the systems worked perfectly.

Sometime later, a cylindrical container with Russian and French inscriptions arrived from France at the Sheremet'yevo airport: it was sent by the National Space Research Center (NSRC) in France, and was delivered to the Space Research Institute of the Academy of Sciences of the USSR. Inside the container was the French satellite protected by spring shock absorbers. Afterwards, a special commission "examined" the small independent satellite according to the program. This check convinced the specialists that the vehicle was ready for space flight.

Scientific information will soon be received by a network of ground stations in France, and measurement results will be sent to the Soviet Union.

Now, Soviet and French specialists are discussing the possibility of using small independent satellites for future research. These space experiments can help designers in France and the Soviet Union to solve important technical problems, and increase the fruitful cooperation between scientists of both countries.

"Polar Morning"

(TASS)

"Pravda", June 14, 1972.

The Soviet-French Meteorological Experiment

A scientific expedition returned to Obninsk after a three-month stay in the Arctic. It conducted an experiment called "polar morning" at the Polar Hydrometeorological Observatory im. E. T. Krenkel', together with French scientists. A series of meteorological rockets, containing Soviet and French scientific equipment, was launched from the island of Hayes (Franz Josef Land) to altitudes from 90-180 km.

The head of the central design office of the Hydrometeorological Service, V. Teslenko, a Candidate of Technical Sciences, gave a report to the TASS correspondent:

"The 'polar morning' is an important step in studying the upper layers of the atmosphere. It is of scientific and practical interest since, according to one theory, the formation of the earth's weather begins at great altitudes near the North Pole. One important factor of the experiment was that it was conducted at the transition time between winter and summer and from polar night to polar day.

As a result, information was obtained on the temperature of the atmosphere, the speed and direction of the wind, the cloud state, corpuscular radiation and solar activity.

New research will enable us to discover the laws which are the basis of these mysterious natural phenomena."

Fruitful Cooperation

"Pravda", July 6, 1972.

Paris, S. (TASS). At the request of French scientists, the /201
Academy of Sciences of the USSR sent to the French National Space Research Center samples of lunar soil brought back to earth by the Soviet Luna-20 automatic station.

"These samples," said Jean-Fancois Denisse, the president of the National Space Research Center, in a conversation with the TASS correspondent, "have been distributed among eight French laboratories, which have already analyzed lunar soil samples brought back by the Luna-16. Work on the new samples is a continuation of research already begun. By studying samples, collected by the Luna-16 station, French scientists discovered much about the history of the formation and age of the moon."

The president of the National Space Resarch Center said that many contacts had been established between French and Soviet scientists, which will help to coordinate their work and, in this way, improve the results obtained.

There are now good prospects for the further cooperation in space research between French and Soviet scientists. This, to a great extent, is the result of the 7th session of the permanent joint Soviet-French commission on scientific and technical and economic cooperation which took place recently in Paris.

The Soviet Union and France: Future Cooperation

(TASS)

"Izvestiya", September 30, 1972.

A conference between Soviet and French scientists and specialists, devoted to the research and use of outer space for friendly purposes, ended on September 27 in Tbilisi. The Soviet delegation at the conference was headed by Academician B. N. Petrov, the chairman of the committee for international cooperation in the research and the use of outer space (Interkosmos) of the Academy of Sciences of the USSR, and the French delegation was headed by Jean-Francois Denisse, the president of the French National Space Research Center.

Summing up the joint work for the year since the previous conference, scientists concluded that cooperation was successfully developing in studying outer space, space meteorology, aeronomy, and communication.

Research into polar aurora, carried out by the Oreol satellite in the Arkad project, the study of low-energy particles and gamma rays of solar origin by the Prognoz-2 station (the Kalipso and Sneg experiments), were very fruitful. Launches of meteorlogical satellites from the island of Hayes, giving new information on the upper layer of the atmosphere in polar latitudes, carried out by specialists of both countries were well-known.

The conference, which took place in a business-like and friendly atmosphere, discussed future projects in great detail. In particular, an agreement was signed for organizing the launches of Soviet

meteorological rockets on the island of Kerguelen in the Indian Ocean. Possibilities were discussed for joint research into space biology and medicine.

Lunar Soil for French Scientists

(TASS)

"Pravda", December 20, 1972.

On December 19 in Moscow, A. P. Vinogradov, the vice-president /202 of the Academy of Sciences of the USSR, gave French scientists more lunar soil samples brought back by the Soviet Luna-16 and Luna-20 automatic stations. The samples are intended for research in French laboratories.

An Agreement between the USSR and the USA on Cooperation in the Research and Use of Outer Space for Friendly Purposes

"Pravda", May 31, 1972.

The Union of Soviet Socialist's Republics and the United States of America,

by taking into account the role played by the USSR and the USA in the research and use of outer space for friendly purposes,

striving for further expansion of cooperation between the USSR and the USA in the conquest of outer space for friendly purposes,

observing the positive experience of cooperation in this field acquired by the parties,

wishing to use the results of scientific research, obtained in the exploration of space for friendly purposes, for the benefit of the peoples of the two countries and peoples of the world,

taking into consideration the provisions of the Agreement on the principles of the nations into the research and use of outer space, including the moon and other heavenly bodies, and also agreements for the rescue of astronauts, the return of astronauts and objects launched into outer space,

in accordance with the Agreement between the Union of Soviet Socialist Republics under the United States of America on the exchange and cooperation in science, technology, education, culture and other spheres of activity, signed on April 11, 1972 and for the further development of the principles of the mutually beneficial cooperation between the two countries,

have agreed to the following:

Article 1.

The parties will develop cooperation in space meteorology, the study of the natural medium, research into near space, the moon and planets, space biology and medicine, and in particular, will cooperate to adopt the required measures to stimulate and carry out the "Final Document on results of discussion of questions of space research between the Academy of Sciences of the USSR and the NASA in the USA" from January 21, 1971.

Article 2.

The parties will carry out this cooperation through the mutual exchange of scientific information and delegations, the organization

of meetings between scientists and specialists of both countries, and also in other forms, through which mutual understanding can be /203 achieved. Joint working groups may be formed for developing and implementing the appropriate cooperation program.

Article 3.

The parties have agreed to work to produce joint facilities for the rendezvous and docking of Soviet and American manned spacecraft and stations to increase the safety of man in space and enable further, joint scientific experiments. The first experimental flight for testing these facilities, envisaging the docking of the Soviet Soyuz spacecraft and the American Apollo spacecraft with mutual interchange of astronauts, is to be carried out during 1975. This will be done on the basis of principles and procedures to be developed in accordance with the "Final Document of the meeting between representatives of the Academy of Sciences of the USSR and the NASA in the USA on the question of producing joint facilities for the rendezvous and docking of Soviet and American manned spacecraft" from April 6, 1972.

Article 4.

The parties will contribute by international efforts to solve international legal problems of research and use of outer space for friendly purposes to establish law and order in space and the further development of international space law, and will cooperate in this direction.

Article 5.

The parties may, by mutual consent, determine other areas for cooperation in the research and use of outer space for friendly purposes.

Article 6.

This agreement comes into force on the day it is signed and will be valid for five years. It may be altered and extended if both parties agree.

Completed on May 24, 1972 in Moscow in two copies, each in Russian and English, whereby both texts have identical validity.

For the Union of Soviet Socialist Republics: A. Kosygin, Chairman of the Council of Ministers of the USSR.

For the United States of America: Richard Nixon, President of the United States of America.

Space -- The Arena for Cooperation

B. N. Petrov (TASS)

"Pravda", May 31, 1972.

Q: What importance do you attach to the agreement, signed between the governments of the USSR and the USA, for the research and use of outer space for friendly purposes?

A: It is difficult to overestimate the treaty which has just /204 come into effect. It envisages the cooperation in the research of near space, the moon and planets of the solar system, the natural medium, space meteorology, biology and medicine. It is proposed to

produce joint facilities for the rendezvous and docking of Soviet and American manned spacecraft in space. The agreement is attempting to increase the safety of man in space, and to carry out joint scientific experiments in the future.

As a result of talks, previously held by specialists from the Academy of Sciences of the USSR and the NASA, the technical aspects were discussed for producing joint facilities for rendezvous and docking in space. The solution of these problems requires joint efforts, and many technical difficulties must be overcome. It was found that it was necessary to carry out joint space experiments to check the technical solutions, guaranteeing the compatability of rendezvous and docking facilities. The first experimental flight for testing these facilities, as was envisaged in the final agreement, should take place in 1975. It is intended to dock a Soviet Soyuz spacecraft and an American Apollo spacecraft in space, with the mutual interchange of astronauts. Much work must be done by Soviet and American specialists to prepare this unique experiment.

Cooperation between Soviet and American scientists into space research has been taking place for several years. The present agreement envisages measures necessary to assimilate and bring into effect understanding between the Academy of Sciences of the USSR and NASA on the cooperation into space research for friendly purposes, which was reached in January 1971.

In accordance with the final document, accepted as the result of discussing questions of cooperation between the Academy of Sciences of the USSR and NASA, some work has already been done

into outer space research, and in space meteorology, biology and medicine. For example, there was an exchange of information on the results of scientific research, obtained during simultaneous experiments using Soviet Mars-2 and Mars-3 interplanetary stations and the American Mariner-9 interplanetary station. There was an exchange of information of radar investigation of Venus, carried out by the USSR, and Mars, carried out by the USA. There was also an exchange of catalogues of lunar maps, photographs of the lunar surface, and lunar soil samples, brought back by the Soviet Luna-16 and Luna-20 automatic stations and by American astronauts in the Apollo spacecraft.

An agreement was reached on the exchange of the results of research into the natural medium using space facilities. It is intended, in the future, to carry out a coordinated experiment into thermal sounding of the atmosphere using satellites from both countries. This is of interest for the space "weather service".

There already exists an exchange of results of meteorological research using rockets and satellites. A joint Soviet-American work is being produced "Fundamentals of space biology and medicine."

There is no doubt that the agreement signed between both governments on cooperating in the research and use of space for friendly purposes will bring about the development of joint work by Soviet and American scientists and specialists in this important field.

Q: What is the future for international cooperation in the research and conquest of space?

A: With the development of space science and the emergence /205
of new possibilities for carrying out direct space research, the task of conquering outer space, investigating the moon and planets of the solar system, the link between the Sun and the earth, and the study of the earth's resources from space, are becoming more complex and wide-spread. Scientists from various countries are proposing new ideas for organizing space experiments. Many of these ideas are of a global nature. In other words, space is becoming an arena for wide international cooperation and requires the joint efforts of many countries and, of course, countries which have more experience in the research and development of outer space.

The Soviet Union has been cooperating with a number of countries for many years. A joint research program, Interkosmos, is being carried out by socialist countries. In accordance with an agreement, ratified five years ago by Bulgaria, Hungary, the German Democratic Republic, Cuba, Mongolia, Poland, Rumania, the Soviet Union and Czechoslovakia, cooperation is being developed in space physics, meteorology and aeronomy, space communication, biology and medicine. Six satellites in the Interkosmos series and two geophysical rockets for vertical sounding of the atmosphere have already been launched, and wide research is being carried out in space meteorology. Many countries are participating in joint research, linked with the optical observation of artificial earth satellites. Last November an agreement was signed

to set up an international space communication system "Intersputnik".

Much joint work is being done as a result of an agreement with France. An angle reflector for laser location of the moon was fitted into the Soviet Lunokhod-1. The Soviet Mars-3 interplanetary station, with French equipment, carried out a joint experiment in the Stereo project (investigating radio-frequency radiation of the Sun in the meter radio wave band). In the joint Arkad project, an Oreol satellite was launched with scientific equipment, developed by Soviet and French scientists. The French small independent satellite and the Molniya-1 communication satellite were put into elliptical orbit simultaneously by a Soviet launch vehicle. Research has been carried out on magnetic and associated points on earth: the Arkhangle'sk region and the island of Kerguelen in the Omega project. Joint meteorological research into the atmosphere is being carried out regularly.

There is active cooperation in space research between scientists from the Soviet Union and India. Joint work has been carried out for some time in probing of the atmosphere using Soviet meteorological rockets from the Indian international equatorial proving ground. Recently, an agreement was signed between both countries for launching an Indian artificial earth satellite using a Soviet launch vehicle.

There is an arrangement for the exchange of scientific information between the Academy of Sciences of the USSR and the European Space Research Organization (ESRO).

An agreement was signed between the USSR and the USA for cooperation in research and the use of outer space for friendly purposes, and is a new important step in developing international cooperation in a sphere so closely linked with technical progress.

The Soyuz and Apollo Joint Flight Project

B. Petrov, Academician and Hero of Socialist Labor

"Pravda", August 2, 1972.

A meeting was held between Soviet and American specialists /206 to prepare the joint flight and docking of Soyuz and Apollo spacecraft. The technical aspects for this flight were examined during preliminary talks between representatives of the Academy of Sciences of the USSR and NASA. At the manned flight center at Houston (USA) a meeting was held between specialists from the Academy of Sciences of the USSR and NASA, where technical and organizational questions on developing joint facilities for the rendevous and docking of the Soviet Soyuz spacecraft and the American Apollo spacecraft, and the flight preparation for them, were comprehensively discussed.

During this meeting the basic technical requirements for the rendezvous and docking systems, the principle of building joint docking facilities and a project for carrying out the flight were agreed upon.

The meeting took place in a business-like atmosphere, and many difficult problems were discussed for carrying out this complex space experiment and solutions acceptable for both parties. Some

questions need to be discussed and agreed upon during subsequent meetings of working groups of Soviet and American specialists. However, an understanding has already been reached which will mean the further development of joint facilities for rendezvous and docking, and preparing the joint spacecraft flight.

What are the aims and the features of the flight?

Equipping manned spacecraft and stations with joint rendezvous and docking facilities will increase the safety of manned flights in space. These facilities will allow any spacecraft or orbital station, if necessary, to dock with any other spacecraft equipped with such facilities, irrespective of the country to which they belong.

The main task of the experimental flight of the Soyuz and Apollo manned spacecrafts is to check the technical decisions taken and test the joint rendezvous and docking facilities of the spacecraft, and the systems for transferring astronauts from one spacecraft to another. The production of joint facilities does not envisage developing identical equipment. Each party will design and produce them independently, but they will be based on general principles and requirements agreed upon.

Technical difficulties which arise are due to the fact that, until now, each country has developed rendezvous and docking facilities in accordance with its own program, therefore, in the future new design principles must be sought which are suitable for docking any two spacecraft which need to be docked. The joint work of

Soviet and American specialists have already found such principles, and ways have been discovered to overcome these difficulties, although much is still to be done to bring these technical decisions into reality.

A peripheral design has been developed using a so-called "androgynous" docking device. It is completely new, has not been used by either country and will allow any spacecraft equipped with it to take an active or passive role. Astronauts pass from one spacecraft to another through internal hatches without going into space.

At the present time, one needs two different types of docking /207
devices, an active and passive, to carry out docking. The main difference in this new system is that, instead of the active docking device having a central shaft and the passive one a docking cone, each of them has guide "lobes" around its circumference, coupling devices and locks and hatches in the central section for the transfer of astronauts.

Another innovation is a special docking compartment, which is the main section of the Apollo spacecraft and on its free face has a docking mechanism, compatible with the corresponding mechanism of the Soyuz spacecraft. This compartment will serve as an air lock for atmospheric adaption when astronauts are transferred. The reason for this is that the atmosphere in the Soyuz spacecraft is normal air at a pressure of 760 mm Hg, and the atmosphere in the Apollo is pure oxygen at a pressure of 260 mm Hg. Probably, in the future the atmosphere of all spacecraft will be close to that of

earth, then a special air lock, similar to that being produced for this flight, will not be required.

Attention is also being paid to the compatablity of spacecraft docking facilities, and radio equipment for communication between spacecraft and ground control centers, including direct voice transmission systems (radiotelephone from one crew to another during rendezvous and docking. It was decided that the air crews should be taught each other's language, to understand voice communications and learn the correct responses. The astronauts will familiarize themselves with the spacecraft of the other country, carry out joint training, and also joint tests of the newly developed rendezvous and docking systems.

A sequence for the flight has been agreed upon. It will take place in the second half of 1975. The Soyuz spacecraft will be launched first from a Soviet cosmodrome. Approximately 7.5 hours later, the American Apollo will be launched. There is a possibility that the Apollo will be launched on the second, and on the third day after the Soyuz launch. The Apollo will carry out an independent flight for approximately a day and afterwards the spacecraft will rendezvous and dock. When docked, they will form a manned space system, which will be controlled and stabilized as a single unit. The orbital flight will last approximately two days. During this time, it is planned to transfer the astronauts from one craft to another and conduct scientific and technical experiments. Television pictures will be transmitted to earth. Then the astronauts will return to their own spacecraft and undocking will take place.

They will fly according to their own program, the Soyuz will land in the Soviet Union, and the Apollo in the waters of the Pacific Ocean.

Much intense work must be done by both parties and many difficulties must be overcome for this flight.

The realization of this joint project is an important step forward in the development of international cooperation in the research and use of space for friendly purposes. There is no doubt that cooperation in this field of technical progress will contribute greatly to the conquest of space for friendly purposes, and the interests of science, and technology of all nations.

A Meeting between Soviet and American Researchers

(TASS)

"Pravda", October 10, 1972.

A conference began between Soviet and American specialists at /208
the Space Research Institute of the Academy of Sciences of the USSR on October 9 in Moscow, during which technical problems will be discussed in the project for the rendezvous and joint flight of the Soyuz and Apollo spacecraft.

The working groups taking part in this project included the Soviet astronaut A. S. Yeliseyev and the American astronaut Thomas P. Stafford.

Soviet specialists demonstrated a model of the docking device, developed in the Soviet Union in accordance with the coordinated

principles and the general method of docking the two spacecraft in orbit.

The conference between these working groups will last ten days.

Soyuz -- Apollo

D. Dmitriyev, a TASS observer

"Trud", October 22, 1972.

The Joint Flight Project

In Moscow a conference has ended between Soviet and American specialists, who have been discussing technical problems for carrying out the joint flight of Soyuz and Apollo manned spacecraft.

At the requests of journalists from the two countries, participants in the conference met with representatives of the Soviet and American press, told them of the progress made, and of the joint work envisaged by the agreement between the USSR and the USA. The meeting, which took place in the presidium of the Academy of Sciences of the USSR, was opened by Academician B. N. Petrov -- the chairman of the Interkosmos Council, attached to the Academy of Sciences of the USSR. In particular, he said that preparations for the joint space experiment are continuing successfully.

An agreement has been reached on a number of technical problems. A wide range of questions is being discussed on the mechanics of the space flight, the on-board equipment in the spacecraft, and the crews' life-support system. Preparation has already reached

the stage when the participation of astronauts, Soviet and American, has become necessary and useful in working conferences.

Then, Academician B. N. Petrov introduced members of the Soviet delegation: Professor K. D. Bushuyev, a corresponding member of the Academy of Sciences of the USSR; A. S. Yeliseyev, and A. G. Nikolayev, space pilots of the USSR. The head of the delegation of American specialists, Dr. Glenn Lanni*, introduced his colleagues to the journalists -- astronaut Thomas P. Stafford, and Ed Anderson, a worker from NASA. The press representatives asked the astronauts to tell them of problems which were discussed in Moscow and of Thomas Stafford's opinions on "Zvezdnyy gorodok", where he was a guest of his Soviet colleagues.

The American astronaut stressed, when answering this question, that the approach to preparation and training programs for the crews in the USSR and in the USA, in essence, are identical.

"In 'Zvesdnyy gorodok'," he said, "I 'piloted' a Russian Soyuz spacecraft using simulators. Practically all operations in controlling this vehicle in space are done as we do them. Of course, the design of some assembly units and components is different, as are the control sticks. However, the methods and technique of 'piloting' and the sequence of many operations are the same."

We discussed with Aleksey Yeliseyev and Andriyan Nikolayev /209 questions for training and selecting the crews, and training features for joint operations in space.

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* Translator's Note: Names, unless known, are transliterated directly from the Russian.

"During our meeting in Moscow, which preceded this one in Moscow, we decided that the crews would begin joint training approximately two years before the flight. If I am a good mathematician, this will take place during next summer. Therefore, the selection of crews must be made earlier. Our present meeting is an important step for carrying out this decision."

"I would like to add," said Aleksey Yeliseyev, when he ended his talk with the journalists, "that at the meeting we were involved in questions for producing joint on-board documentation for crews, discussed in general details the best way to organize work and rest during the flight, and settled questions for the work of astronauts with flight control centers and radio procedure between spacecraft. There were no differences of opinion, and all that was needed to be solved on this stage of preparation was solved."

Andriyan Nikolayev, in his answer, dwelt on one important problem, upon which the success of the space operation depends: overcoming the "language barrier" between the Soyuz and Apollo crews.

"Of course, scientists and specialists are doing all they can to simplify the astronaut's work in space. It has already been decided to prepare a work plan for the crews at all stages of the experiment: during take-off, the joint search and rendezvous of the vehicles in space, during docking, joint flight, undocking and removal from each other. But this does not mean that this can be done without a thorough knowledge of languages. At present, there are no astronauts among the Soviet or American crews capable of

speaking fluently in both languages. However, I am convinced that we shall soon speak English and Russian. This will help the joint training of crews envisaged in the space experiment program."

The heads of the Soviet and American delegations at the conference in Moscow were asked several questions during the meeting between scientists and journalists.

Professor K. D. Bushuyev said:

"It is impossible to imagine how Soyuz and Apollo spacecraft could be prepared without difficulty for a flight using docking. These spacecraft were built in different countries and, naturally, are different in design and in on-board equipment. During their development, specialists in the Soviet and Union and in the United States did not intend these vehicles to be docked in space. Therefore, both vehicles had to be greatly adapted for docking in space.

A special docking unit had to be produced and tested, the design of which was based on experience accumulated by the Soviet Union and the United States. Of course, there will be a number of basic differences.

The docking device will enable crews to transfer from one spacecraft to the other through an inner tunnel without going out into space. It was decided to build it so that both the Soyuz and Apollo could dock, and assume the role of an active or passive partner. In the Apollo, the artificial atmosphere consists of pure oxygen. Therefore, the pressure in the American vehicle is relatively low, in the order of 300 mm Hg. The Soyuz uses a mixture of

nitrogen and oxygen, and the barometric pressure is almost the same as the earth's atmosphere at sea level -- 750-800 mm.

This alone complicates the problem of the atmospheric "com- /210
patability" of the two vehicles. It was decided to build a transition compartment which would solve a number of important problems, including atmospheric "compatability". Soviet and American specialists developed and examined several versions. At the present time, we are close to the final solution of this problem. I believe that we shall find the best version."

Later, K. D. Bushuyev spoke of the changes which must be made to the Soviet spacecraft in order for the docking and joint flight with the Apollo to be made.

"The Soyuz must have modifications made to its rendezvous equipment, special orientation signal lights and communication equipment must be installed, and antenna arrangements and on-board systems and instruments must be adapted for docking."

Journalists were interested in the question: "Will all the astronauts be guests of each other?" K. D. Bushuyev said that the mutual transfer program had been previously discussed by specialists, but will be examined and finally confirmed during the next meeting. The experiment is calculated so that crews from both vehicles can stay in the Soyuz and Apollo. We are attempting to arrange the flight so that the full complement of both spacecraft can stay in one vehicle.

Dr. Glenn Lanni, the head of the American delegation, elaborated on the Soviet scientist's answer.

"I believe that Professor K. D. Bushuyev has clearly explained the changes which must be made to the Soviet and American spacecraft. It remains for me to say that we have arranged in principle the manner in which the joint work on the Soyuz-Apollo project will be done.

Beginning in the middle of next year, and during the next 12 months, we shall carry out preliminary tests and experiments. Later, we shall start producing equipment for the flight. By this time, the joint flight program will be worked out in detail and, in this way, in 1975 the equipment, crews and ground flight and control services will be ready for work."

Press representatives were also interested in the effect the Soyuz-Apollo project would have on the development of manned space flights. B. N. Petrov answered this question.

"As is known, the agreement between the governments, in particular, envisages the production of joint rendezvous and docking facilities for spacecraft launched by the Soviet Union and the USA.

Producing these facilities and equipping spacecraft with them will be of value to crews who may need them for one reason or another. They will be used by one spacecraft when it is near another in space. In this way, this experimental flight is more wide and complex than simply docking Soviet and American spacecraft. As a result of it, important problems will be solved necessary for manned flights in space, irrespective to whom those manned

spacecraft belong. Apart from this, they will enable joint experiments to be conducted in space."

A Joint Conference

"Pravda", November 25, 1972.

New York, 24. (TASS). A joint technical group conference /211 between American and Soviet experts on preparing the first joint Soviet-American space flight began at the Manned Space Flight Center in Houston (Texas).

In accordance with the Soviet-American agreement on cooperation in the research and the use of outer space for friendly purposes, the first docking in space between the Soviet Soyuz and the American Apollo and their joint flight is planned for 1975.

Tests on Models

(TASS)

"Pravda", December 16, 1972.

A meeting between Soviet and American specialists, working to produce joint docking facilities for the Soyuz and Apollo spacecraft, took place in Moscow from December 7-15. During the meeting there was duscussion and agreement on technical questions, and tests on working scale models of the crafts' docking devices were made. They were the first of preplanned joint tests.

Next year meetings between specialists and joint tests will be continued.

An Exchange of Lunar Soil

(TASS)

"Pravda", April 14, 1972.

On April 13, representatives from NASA (USA) visited the presidium of the Academy of Sciences of the USSR. Lunar soil samples, brought back to earth by the Soviet Luna-20 automatic station, were distributed. At the same time, Soviet scientists were given a lunar soil sample brought back by the American Apollo-15 spacecraft.

The exchange was made in accordance with the agreement between the Academy of Sciences of the USSR and NASA, signed in January 1971.

A Search in Space

I. Shklovskiy, a corresponding member of the Academy of Sciences of the USSR,
L. Matveyenko, a Candidate of Physical and Mathematical Sciences

"Izvestiya", May 17, 1972.

Modern science is boldly attacking problems, the solution of which ten years ago would have seemed impossible owing to the great difficulties for carrying out large-scale experiments and research. One way for overcoming these difficulties is the development of international cooperation between scientists, and the joint participation of scientific organizations from different countries in studying nature's mysteries. An example of this is global research of the weather and climate of the earth and the study of oceans.

Not only the earth, but far space will become the arena for world scientific cooperation. In particular, Soviet and American radio astronomers are conducting joint work in studying recently /212 discovered space objects, many billions of light years from the solar system. The observations, which were conducted in observatories at great distances from each other, have provided new information for world science.

This article shows the problems which are being studied by radio astronomers in the USSR and the USA.

Among the many wonderful achievements in astronomy recently, possibly, the most important was the discovery of completely new types of space objects: quasi-stars or quasars in star formation and planetary systems. Analysis of radio astronomical and optical observations of quasars shows that they are at great distances from us, deep in the universe. These distances are so great that, on account of the so-called red displacement, electromagnetic waves radiated by quasars are "lengthened" 2-3 times. This can only occur if the distance to their source is approximately 10 billion light years.

The radiation power of quasars is enormous -- this is why they can be observed from extremely large distances. Moreover, one unexpected fact is that these objects are comparatively small - less than one light year. The size of large galaxies (such as our stellar system, with more than 150 million stars) is approximately 100,000 light years, but the radiation power is tens of times smaller than quasars. This means that quasars are very "compact" objects,

where enormous energy is produced in a relatively small volume.

Information on the small size of quasars was obtained by analyzing the astonishing fact that their radiation varies with time. Noticeable changes of brightness are observed over a few weeks or even days. However, to understand the nature of processes taking place with this huge generation of energy, it is important to check the density of quasars not by an indirect, but a direct method, and measure their structure in detail and its change over time.

No less interesting and mysterious objects were some nebulae in our Galaxy, which have been known for some time but have only recently been isolated. Apparently, they have small, individual regions radiating enormous power in narrow radio wave spectra corresponding to lines of the so-called hydroxyl and water vapor. These bright lines must be linked with very active processes differing from those already known. Radiation of these lines changes quite rapidly, sometimes over a few minutes. This indicates that the size of the source is less than one astronomical unit and, consequently, smaller than our planetary system. Possibly, we are observing regions where condensation of interstellar gas, and the formation of stars and planets from it occurs.

Academicians N. Basov and A. Prokhorov, and the American scientist C. Towns were awarded the Nobel Prize for the discovery of a new mechanism for amplifying electromagnetic waves -- the

so-called maser mechanism -- which, apparently, led one to assume that something similar happens in space.

Study of the physical conditions for the formation of stars and planetary systems and processes which accompany them are of fundamental value. Until now, practically nothing is known on how stars and planets are formed. In order to do this, one needs to carry out detailed research into the structure of regions where this star formation process occurs. Radio astronomers expected to meet great difficulties here. Both quasars and compact formations /213 in nebulae are visible at angles of less than one thousandth of a second of arc, and individual "details" of these objects have even smaller angular measurements. To understand the minuteness of these dimensions, one must imagine the angle at which we "see" an astronaut on the moon.

The accuracy of measurement with extremely good optical telescopes is only approximately 1 sec. This gives the so-called "resolving power" of the instrument -- its capability to detect small details on the object image. The resolving power is determined by the ratio of the wavelength of the received radiation to the telescope diameter.

The resolving power, even for very large radio telescopes, is low owing to the relatively large wavelength of radio-frequency radiation. More than 20 years ago, radio astronomers learned to overcome this difficulty by using an interference method. The essence of this was that observations were done simultaneously with two radio telescopes, at a considerable distance from each other,

linked by a high-frequency cable. Signals received from the radiation source were transmitted along this cable and compared. With this method of observation, the resolving power was determined not by the antenna diameter, but the distance between the radio telescopes. Since this could be considerable, the resolving power was significantly increased in comparsion with normal observations. However, the technical possibility for transmitting radio signals is no more than a few tens of kilometers.

In 1963 Soviet scientists suggested a radio interference method to overcome this "barrier" and obtain whatever resolving power was required. Signals, received by radio telescopes, were recorded on magnetic tapes which were afterwards taken to a computation center and processed together.

In 1969 and 1971 Soviet and American scientists from the Space Research Institute of the Academy of Sciences of the USSR, the Crimean Astrophysical Observatory, the Physical Institute im. P. N. Lebedev, the California Technological Institute, the Cornell University, the Massachusetts Technological Institute, the Marine Research Laboratory, the National Radio Astronomical Observatory, the Smithsonian Observatory and the Haystack Observatory used this method for observing compact objects. The most sophisticated radio telescopes in the world were used in this experiment: the Crimean Astrophysical Observatory near Simeiz, the American National Radio Astromonical Observatory, the NASA Long-Range Space Communication Center and the Haystack Observatory. Areas where stars and

planetary systems are formed were studied on a 1.35 cm wave, and quasars and nuclei of galaxies on 6, 3.55 and 2.8 cm waves. The antennas were at the greatest possible distance from each other which gave the maximum angular resolution, obtainable on earth, of several ten-thousandth fractions of a second.

The high angular resolution made it possible to establish that quasars have a complex structure and, as a rule, consist of several components. In a number of cases, these components had such small angular dimensions that even the maximum resolution was insufficient to investigate them. In cases when the angular measurements could be determined, it was found that their radio-frequency radiation was determined by electrons, moving in magnetic fields at a speed close to that of light.

The mysterious regions in gas nebulae are also of a complex structure, but consist of individual, very compact formations moving at different speeds. It was not possible to measure the /214 angular dimensions of individual components, since one needs a higher angular resolution for this. In particular, one of the components in the "W49" source has angular dimensions less than the doubled diameter of the earth's orbit, and its temperature was greater than 10^{15} (unit with 15 zeros) degrees.

It follows from the results obtained that a new increase in angular resolution is required for further research. Therefore, Soviet and American scientists are developing an interferometer project by taking one of its elements into outer space.

Space Cartography

"Krasnaya Zvezda", September 20, 1972.

New York, September 19. (TASS). The cooperation between the USSR and the USA in the research and use of outer space for friendly purposes is successfully developing. Specialists from the Academy of Sciences of the USSR and NASA have exchanged documentation on lunar coordinate systems and mapping of the moon. They have agreed on the joint development of basic principles for making lunar maps, to compile a map of the moon on a scale of 1:5,000,000.

They will also develop an overall base system of selenographic coordinates. Specialists of both countries have agreed to a periodic exchange of information concerning new projects and proposals in this sphere.

An Agreement Is Signed

(TASS)

"Pravda", May 11, 1972.

A Soviet-Indian agreement on the further development of cooperation in space research was signed on May 10 in the presidium of the Academy of Sciences of the USSR.

The agreement was signed by the president of the Academy of Sciences of the USSR, Academician M. V. Keldysh and Professor M. G. K. Menon, the chairman of the Indian Space Research Organization of the Indian government.

Krishnarao Shivarao Shelvankar, the Indian ambassador in the Soviet Union, was present at the signing ceremony.

During their stay in the Soviet Union, the delegation of Indian scientists, headed by M. G. K. Menon, had talks with the president of Academy omy of Sciences, M. V. Keldysh and other leading scientists, and questions for the further cooperation between scientists of both countries were discussed.

The Plans of Indian Scientists

I. Shchedrov

"Pravda", September 7, 1972.

Delhi, 6. ("Pravda's" own correspondent). "India will launch its first satellite into near-earth orbit in 1974." said Professor M. G. K. Menon, the president of the Indian Commission for Electronics. Newspapers in Delhi printed this report on their front pages. Indian scientists and engineers have already produced working drawings of a 250 kg satellite, which will be built completely from components made in India. Shortly, approximately 500 scientists and technicians will begin work. According to /215 newspaper reports, the first Indian satellite will be launched from a Soviet cosmodrome, in accordance with the Soviet-Indian agreement on the further development of cooperation in space research, signed in May of this year in Moscow. Later, launches will take place from the rocket firing station at Tkhumba, in the extreme south of India, which is already in operation.

Lunar Soil Samples Are Handed Over

(TASS)

"Pravda", December 13, 1972.

On December 12 in Moscow, Academician A. P. Vinogradov, the vice-president of the Academy of Sciences of the USSR, handed over lunar soil samples, brought back by the Luna-16 and Luna-20 Soviet automatic stations, to a representative of the Indian Academy of Sciences.

Lunar Soil Is Being Examined

"Krasnaya Zvezda", November 24, 1972.

Workers at the Czechoslovakian Academy of Sciences have completed the first stage of research into lunar rock samples, taken from the Mare Fecunditatis by the Soviet Luna-16.

Research into the rock, a gift from the Academy of Sciences of the USSR, was conducted by four institutes and research laboratories of the Higher School of Chemical Engineering in Prague, and also the Mining Institute in Ostrava. The sample of investigated rock was divided into 1,300 recorded particles. Various tests, including: so-called neutron active analysis methods, provided much interesting information which will be published in scientific journals and collections.

For Scientific Work

(TASS)

"Pravda", August 25, 1972.

In Moscow on August 24, Academician A. P. Vinogradov, the vice-president of the Academy of Sciences of the USSR, handed over to Professor James Lighthill, a representative of the Royal Society (London), lunar soil samples brought back by the Luna-16 and Luna-20. Laboratories in England will carry out research into the samples.

John Killick, the British ambassador in the USSR, was present at the ceremony.

News Item

(TASS)

"Izvestiya", May 27, 1972.

A meeting was held in Moscow from May 24-26 between scientists from the USSR and the German Democratic Republic, to examine plans for the further development of cooperation in the Interkosmos program.

During the meeting the guests were given soil samples, brought back by the Soviet Luna-16, for research in laboratories throughout the German Democratic Republic.

(TASS)

"Pravda", December 26, 1972.

In Moscow on December 25 an agreement was signed for scientific cooperation between the USSR and the Iraqi Republic. Academician

M. V. Keldysh, the president of the Academy of Sciences of the USSR, signed for the Soviet side, and Dr. Khisham ash-Shaun, the Minister /216 for Higher Education and Scientific Research in the Iraqi Republic, for the Iraqi side.

After the agreement was signed, Dr. Khisham ash-Shaun was given samples of lunar soil brought back by the Soviet Luna-16.

An Agreement Is Ratified

(TASS)

"Pravda", April 6, 1972.

An agreement for setting up Intersputnik, an international system and space communication organization, signed in Moscow on November 15, 1971, was ratified by a decree issued by the Presidium of the Supreme Soviet of the USSR on April 3, 1972.

Credentials Are Deposited

(TASS)

"Izvestiya", April 1, 1972.

On March 31, D'yula Rapai, the Hungarian ambassador in the USSR, deposited with the government of the Soviet Union credentials on the ratification of the Hungarian agreement for setting up Intersputnik, an international system and space communication organization.

(TASS)

"Izvestiya", April 21, 1972.

On April 21, Stoyan Gyurov, the Bulgarian ambassador in the USSR, and Nyamyn Luvsanchultem, the Mongolian ambassador in the USSR, deposited with the government of the Soviet Union ratification credentials of the Bulgarian and Mongolian agreements for setting up Intersputnik, an international system and space communication organization.

(TASS)

"Izvestiya", October 21, 1972.

On October 20, Z. Novak, the Polish ambassador in the USSR, deposited with the government of the Soviet Union credentials on the ratification of the Polish agreement for setting up Intersputnik, an international system and space communication organization.

(TASS)

"Izvestiya", November 30, 1972.

On November 29, Raoul Garcia Pelaes, the Cuban ambassador in the USSR, deposited with the government of the Soviet Union credentials on the ratification of Cuban agreement for setting up Intersputnik, an international system and space communication organization.

At an Intersputnik Session

(TASS)

"Sovetskaya Rossiya", November 30, 1972.

The first session of Intersputnik, an international organization for space communication, finished its work in Moscow. Participating members of the organization came from Bulgaria, Hungary, the German Democratic Republic, Cuba, Mongolia, Poland, Rumania, the USSR, and Czechoslovakia.

The organization council examined questions for implementing /217
the Intersputnik space communication program, and organizational questions.

The first session took place in an atmosphere of cooperation and mutual understanding.

A Convention Signing

(TASS)

"Izvestiya", April 1, 1972.

In Moscow on March 31, Fan'ya la Norind", the Laotian ambassador in the USSR, signed a convention on behalf of his government on international responsibility for damage caused by space objects.

(TASS)

"Izvestiya", June 7, 1972.

In Moscow on June 6, Kh. A. Ibrahim, the Jordanian ambassador to the USSR, signed a convention on behalf of his government on

international responsibility for damage caused by space objects.

(TASS)

"Izvestiya", June 23, 1972.

In Moscow on June 22, John Killick, the British ambassador in the USSR, signed on behalf of the New Zealand government a convention on international responsibility for damage caused by space objects.

Credentials Are Deposited

(TASS)

"Izvestiya", October 5, 1972.

On October 4, Salekh Mahdi Amash, the Iraqi ambassador in the USSR, deposited with the Soviet government an instrument of ratification of the convention on international responsibility for damage caused by space objects.

(TASS)

"Izvestiya", October 21, 1972.

On October 20, N. Luvsanchultem, the Mongolian ambassador in the USSR, deposited with the Soviet government an instrument of ratification of the convention on international responsibility for damage caused by space objects.

(TASS)

"Izvestiya", November 28, 1972.

On November 27, La. Norindr, the Laotian ambassador in the USSR, deposited with the Soviet government instruments of ratification on the activity of states into research and use of outer space, including the moon and other heavenly bodies, and agreements on rescuing astronauts and returning objects launched into outer space.

(TASS)

"Izvestiya", December 29, 1972.

On December 27, D'yula Rapai, the Hungarian ambassador in the USSR, deposited with the Soviet government credentials on the ratification of the Hungarian convention on international responsibility for damage caused by space objects.

The Future Paths of Astronautics

"Novoe vremya", No. 52, 1972.

V. Rozen, a correspondent of "Novoe vremya", met Academician /218
L. I. Sedov and asked for his opinions on the further development of research into the universe.

I remembered the study which I had seen when the first Soviet satellite was launched 15 years ago: the normal workroom of a scientist, piled with books, scientific journals, proofs and manuscripts ... Its owner, Academician L. I. Sedov, as usual, is full of creative plans and energy. He has recently returned from Baku,

where he was occupied not only in scientific but organizational work. He is the chairman of the organization committee for the future 24th Congress of the International Aeronautical Federation, which will be held in the capital of Azerbaydzhan, Baku, in October 1973. It was necessary to carry out there preliminary preparations, since such scientific forums are of a dignified and serious nature. For example, at the congress in Vienna in October 1972, there were more than 500 delegates and many guests from 36 countries: during the week 300 lectures were heard on various subjects ...

Q: Today, at the beginning of the 16th year of the space age, how can one interpret its present stage?

A: If one is talking in wide general terms, I believe that the most important and promising factor is the development and extension of international cooperation in space. I have in mind the desire to work hand in hand and create joint projects.

Of course, the "friendly approach" of the Soviet Union has much to do with the present general improvement of international relations. A breath of warm air was felt at the recent Vienna Congress, which took place in an atmosphere of true, creative cooperation.

The joint solution of complex problems in the further study of the universe and joint concrete technical projects have a great political and practical meaning. It brings about the present increase in the exchange of ideas, eliminates parallelism, and allows the most important and promising projects to be chosen. It has another significant advantage: the further we explore the

universe and the more our knowledge increases, the more complex and serious become new scientific problems. Huge resources are needed to solve these problems. For example, the USA spent the "astronomical" sum of 26 billion dollars on the Apollo Project. Therefore, it is more sensible, and even necessary, to combine the joint sources of two or more countries ...

Q: What is there to be said on the prospects and results during the distant and not too distant future?

A: The Apollo-17 flight is in progress at the moment and all that goes with it. The United States declared that they do not intend to land on the moon again before the end of the century.

This was a very useful program from the point of view of improving space flight technique, developing spacecraft docking in a vacuum, landing and bringing back a manned module from a heavenly body, men staying on the moon's surface, and from the point of view of studying the earth's natural satellite. Probably, data /219 obtained by American astronauts will provide valuable information not only on the nature of the moon's history, but on the age and origin of the earth and other planets.

The moon research carried out by Soviet automatic stations was also extremely fruitful. It showed the usefulness of studying heavenly bodies by automatic means. It is even more important, since when investigating distant planets, such as Venus, Mars and Jupiter, the use of automatic vehicles will be the only practical useful research method for the next ten years or so.

Soviet and American research into Mars and Venus was also extremely fruitful, especially the landing of Soviet automatic stations on these planets. Doubtlessly, these experiments will continue and provide new information. I would also like to wish our American colleagues success in their launch of a space vehicle for research into Jupiter.

As for future plans, mainly there is the Soviet-American program, the first stage of which will be the docking of the Soyuz and Apollo spacecraft in near-earth orbit in 1975, and the transfer of crew members from one spacecraft to another. Much has already been said on this project and I will not dwell on it.

There is a great future for producing manned orbital stations, both from the scientific and national economic points of view. As a matter of fact, the docking and joint flight of Soviet Soyuz-4 and Soyuz-5 spacecraft in January 1969 with their crews of V. A. Shatalov, B. V. Volynov, A. S. Yeliseyev, and Ye. V. Khrunov, was the first experiment in creating an airborne laboratory. An important contribution to astronautics was the flight in 1971 of the Salyut, first Soviet manned space orbital station. Undoubtedly, in the future the production of artificial earth satellite, airborne laboratories, will be the basis of most programs. The USA has a project for setting up a laboratory in space to be launched into earth orbit in 1973.

Astronautics is concentrating on solving many types of purely "terrestrial" problems, which are of great economical value and promise immense technical progress. The Vienna Astronautics

Congress had as its motto "space for world development", and many applied problems were discussed there. The crew of manned stations will be periodically changed and consist of, apart from astronauts, scientists and specialists from different fields -- astronomists, meteorologists, geologists, oceanographers, physicists, chemists, physicians, engineers, agronomists and others. Soviet flights, the crews of which contain "ground" scientists and the fact that Schmitt, an American geologist, landed on the moon, can be seen as the initial steps along this path.

Orbital stations have various uses: an astromonical observatory free of interference from the earth's atmosphere; an observation point, from which one can see in amazing detail not only how to determine the harvest, but to forecast it for an area of only a few hectares; and to carry out geological and geophysical examination of almost inaccessible areas. Such a method may sometimes show oil layers or underground lakes, and useful minerals. Americans, for whom this is a painful question, are planning to expose from space enterprises which are discharging harmful waste into rivers and lakes,and even determine the chemical composition of this discharge.

Orbital stations will also be used as laboratories and production units. /220 Laboratories could carry out various experiments in weightlessness and, if necessary, a vacuum, and workshops could produce in vacuum conditions various new materials, high purity metals, and grow crystals. The first welding in space was done on the Soviet Soyuz spacecraft. Experiments of a productive nature

in weightlessness were conducted in 1971 by American astronauts. In the USA they are already estimating the wide market for "space" products.

The size of orbital stations will gradually be increased, and their crews will consist of from 2-3 to several tens of people, and wherever one looks there will be space settlements forecast by K. E. Tsiolkovskiy.

This may seem a dream today, but a great prophet expected people on the moon in the year 2017, and his prophecy came true almost 50 years before this. Therefore, such settlements are not pure fancy. If one looks back only 15 years, the progress made by man in this short space of time seems fantastic.

Of course, the production of manned stations requires more development. Appropriate rockets must be built to transport and loads in both directions. This will be expensive. However, so-called shuttle flights in spacecraft which can be used many times are being suggested, real space aircraft which can land and take off from less sophisticated cosmodromes than at present. Shuttle flights will cut the cost of space transport considerably.

How can man live in weightlessness? Recent experience showed this is not an easy problem to solve. Probably, artificial weightlessness must be created -- this is completely possible technically. Space biology and medicine are studying other ways.

It is less difficult to feed an astronaut and supply him with water and air. Space greenhouses and poultry farms are being produced, various closed ecological systems are being developed, and

there has been good progress in regenerating water, air and food solutions.

No doubt space electronics will be developed later. Here, as in other extremely technical progressive spheres, there is no real difference between electronics on earth and in space. Recently, a quarter of a century ago, the first computers weighed 30 tons and occupied an area of several tens of square meters: they only made 5,000 computations per minute. Generally speaking, this is not bad, but seems ridiculous in comparison with modern computers, carrying out mathematical operations in a billionth part of a second, and weighing only a few kilograms. Miniaturization of electronic equipment, not only for computing, but in radio, television and other spheres, is taking place at terrific speed. One only needs to mention the distances of hundreds of millions of kilometers from which automatic stations transmit information from Mars: the Soviet Union and the USA have received messages from even greater distances.

Further successes can be expected in this field, and in the use of meteorological, television and other communication satellites which have become a part of modern technology. Scientists from various countries are investigating the possibility of using meteorological satellites not only for forecasting weather, but for controlling it, for example, regulating when and where precipitation occurs.

Development is being made in space communication to organize radio telephone communication and television transmissions not only /221 through relay stations on earth, but directly from satellites in

space to individual receivers. This is quite realistic since the United Nations recently adopted a special resolution concerning the aims and nature of such space television transmissions.

Present satellites do not have sufficient power to do this. More powerful energy sources are needed in space. A more promising new method envisages the use of a laser beam as a transmission channel. In theory, a laser could broadcast millions of television transmissions or billions of telephone conversations.

With the modern ground relay system, communication satellites are more promising, for example, in teaching. This is especially important for developing countries, where there is still a shortage of textbooks, qualified teachers and well-equipped schools. Next year, India will begin to use a satellite, above the equator, for transmitting agricultural and technical information to Indian villages. The programs will be compiled by an experimental station in Akhmabad and gradually, their content will be extended. In Brazil they are planning to organize educational television transmissions for 100,000 schools.

Holography can be most promising. Imagine how amazing it will be to see pictures of planets transmitted from space onto television screens.

This story could be continued, since all this is not fantasy but could happen tomorrow or the day after. Much of what has been said is possible and was discussed scientifically at the congress in Vienna. The main theme dealt with prolonged flights of orbital

stations and scientific and technical problems linked with producing them, in particular, developing space "shuttles".

In bioastronautics there was discussion on the practical use in medicine of methods and instruments developed for space. At the symposium on nuclear energy for space various methods for converting nuclear energy into electrical energy directly on board the spacecraft were discussed ...

It is believed that the next astronautical congress in Baku will provide much new information for this young but rapidly developing science.

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